CHAPTER 4

Small Diameter Gravity Sewers

4.1 Introduction

Small diameter gravity sewers (SDGS) are a system of interceptor tanks and small diameter collection mains. The interceptor tanks, located upstream of each connection and usually on the property served, remove grease and settleable solids from the raw wastewater. The settled wastewater is discharged from each tank via gravity or by pump (septic tank effluent pumping [STEP] unit) into the gravity collector mains usually located in the public right-of-way. The mains transport the tank effluent to a treatment facility or connection with a conventional gravity sewer interceptor.

Because the interceptor tanks remove the troublesome solids from the waste stream, the collector mains need not be designed to carry solids. This reduces the gradient needed and, as a result, the depth of excavation. The need for manholes at all junctions, changes in grade and alignment, and at regular intervals is eliminated resulting in further potential cost savings.

The sewer diameter can also be reduced because the interceptor tank attenuates the wastewater flow to reduce the peak to average flow ratio. Yet, except for the need to evacuate the accumulated solids from the interceptor tanks periodically, SDGS operate similarly to conventional sewers.

The compatibility of STEP systems with SDGS allows an efficient low-cost hybrid collection alternative in many unsewered developments. A hybrid design can often eliminate or minimize the need for lift stations to reduce both capital and operation and maintenance (O&M) costs. It is cautioned that grinder pump (GP) systems are not compatible with SDGS because the waste solids and grease are not removed from the waste stream before discharge to the collector main. Also, effluent sewer termination into vacuum systems could have odor potential at the central vacuum station.

4.2 Description of System Components

Typical small diameter gravity sewer systems consist of: building sewers, interceptor tanks, service laterals, collector mains, cleanouts, manholes and vents, and lift stations (see Figure 4-1). Other appurtenances may be added as necessary

4.2.1 Building Sewers

All wastewaters enter the small diameter gravity sewer system through the building sewer. It conveys the raw wastewaters from the building to the inlet of the interceptor tank. Typically it is a 10-15 cm (4-6 in) diameter pipe laid at a prescribed slope, usually no less than 1 percent, made of cast iron, vitrified clay, acrylonitrile butadiene styrene (ABS) or polyvinyl chloride (PVC).

4.2.2 Interceptor Tanks

Interceptor tanks perform three important functions: 1) removal of settleable and floatable solids from the raw wastewater, 2) storage of the removed solids, and 3) flow attenuation. The tanks are designed for hydraulic retention times of greater than 24 hours when two-thirds full of solids to permit liquid-solid separation via sedimentation and flotation. Outlet baffles on the tanks prevent floating solids from leaving the tank. The tank has sufficient volume to store the solids until which time they can removed, typically on 1-10 year cycles for residential connections and semi-annually or annually for commercial connections with food service. Anaerobic digestion does take place within the tank which reduces the volume of accumulated sludge and prolongs the storage time. The interceptor tanks also provide some surge storage which can attenuate peak flows entering the interceptor tank by more than 60 percent.[1,2]

Septic tanks are typically used as interceptor tanks (Figure 4-2). Pre-cast reinforced concrete and coated steel tanks are usually available locally in a variety of sizes. Fiberglass (fiber reinforced plastic, FRP) and high density polyethylene tanks (HDPE) are also available regionally. Pre-cast concrete tanks are most commonly

Figure 4-1. Components of a small diameter gravity sewer (SDGS) system.

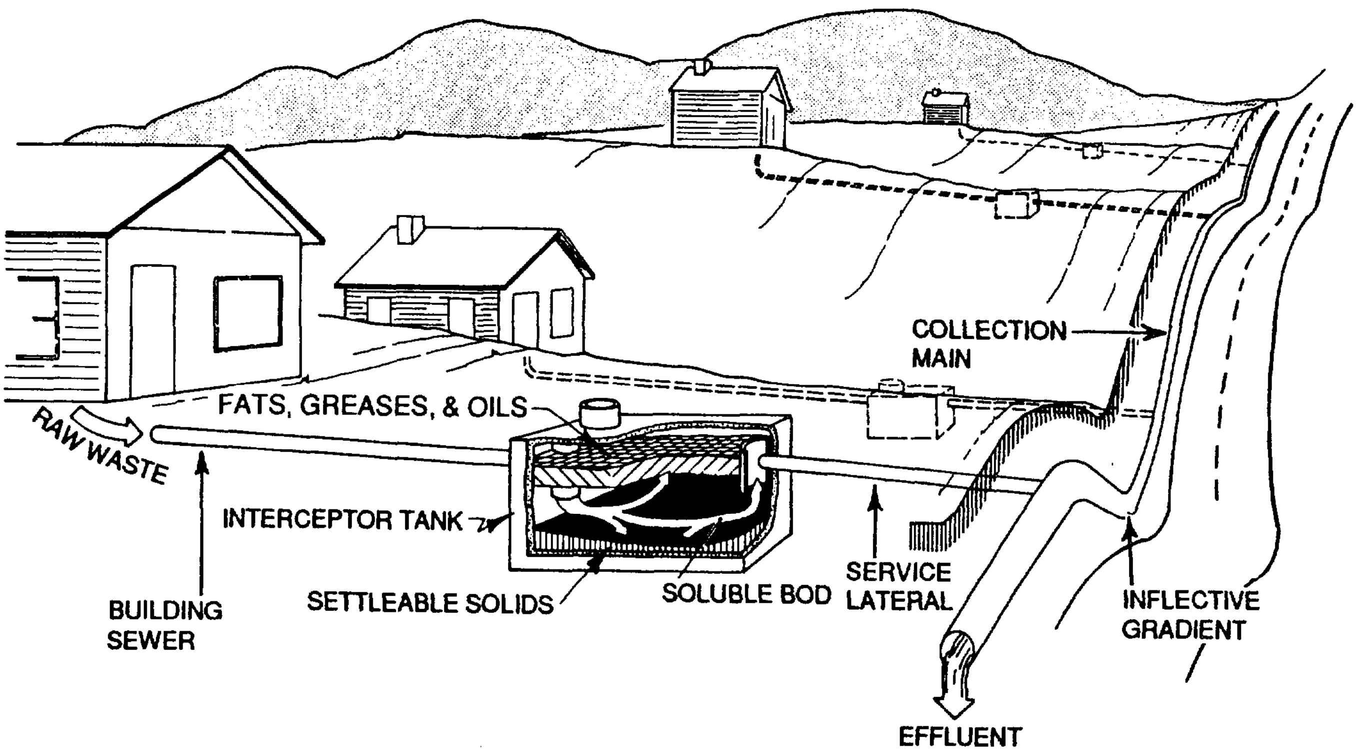
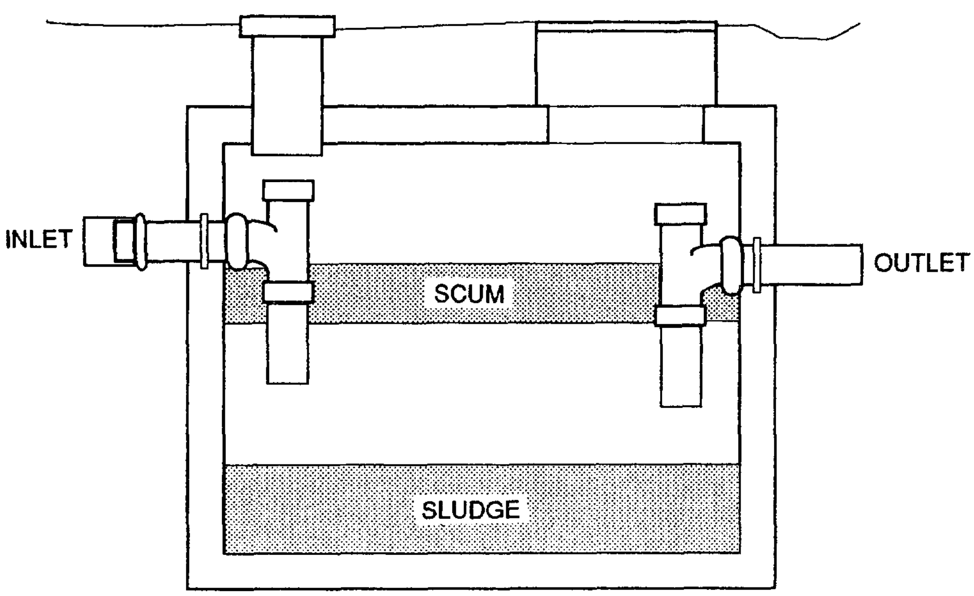


Figure 4-2. Typical pre-cast concrete interceptor tank.



used in SDGS systems, but polyethylene and fiberglass tanks are gaining in popularity because they are more watertight and lighter in weight for easier installation. However, FRP and HDPE tanks require more care in proper bedding and anti-flotation devices where high ground water occurs.

4.2.3 Service Laterals

Service laterals connect the interceptor tank to the collection main. The laterals are usually plastic pipe no larger in diameter than the collector main. They are not necessarily laid on a uniform grade nor with a straight alignment (Figure 4-3).

Optional lateral appurtenances include check valves, "p"-traps or "running" traps and corporation stops. Most existing SDGS systems do not include these options, but check valves are being used more frequently to prevent backups into low-lying connections during peak flows. "P"-traps have been retrofitted on connections where odors issuing from the house plumbing vent stack have been a problem. Corporation stops are used primarily on "stub outs" reserved for future connections.

4.2.4 Collector Mains

Collector mains convey the settled wastewater to either a lift station, manhole of a conventional gravity sewer system or directly to a treatment plant. Plastic pipe, with solvent weld or rubber gasket joints is used almost exclusively. However, flexible, high density polyethylene pipe with heat fused joints has also been used successfully.

4.2.5 Manholes and Cleanouts

Manholes and cleanouts provide access to the collector main for various maintenance tasks. Since hydraulic flushing is sufficient to clean the mains, the use of manholes is usually limited. Common practice is to use manholes only at major junctions because they can be a significant source of infiltration, inflow and sediment. Cleanouts are typically used at upstream termini, minor main junctions, changes in pipe size or alignment, high points, and at intervals of 120-300 m (400-1,000 ft).

4.2.6 Air Release Valves and Vents

Vents are necessary to maintain free-flowing conditions in the mains. In SDGS systems installed with continuously negative gradients, the individual house connections will provide adequate venting if the sewer lateral is not trapped. In systems where inflective gradients are allowed, the high points in the mains must be vented. Air release or a combination of air release/vacuum valves are commonly used in combination with a cleanout (Figure 4-4). Individual connections located at a summit can also serve as a vent if the service is neither trapped nor fitted with a check valve.

4.2.7 Lift Stations

Lift stations may be used at individual connections which are too low in elevation to drain by gravity into the collector. They are also used on the collector mains to lift the wastewater from one drainage basin to another. Individual lift stations are essentially STEP systems and are usually simple reinforced concrete or fiberglass wet wells following the interceptor tank with low head, low capacity submersible pumps operated by mercury float switches (Figure 4-5). In a few systems where the static lift is great, high head, high capacity turbine pumps have been used successfully. This is only possible if the wastewater effluent is screened prior to pumping to eliminate any solids that might clog the turbines. Mainline lift stations were originally similar in design to the "residential" lift stations, but because of corrosion problems which commonly occur in the wet well, the use of dry wells is becoming more common to reduce corrosion problems and to facilitate maintenance.

4.3 System Design Considerations

4.3.1 Hydraulic Design

A small diameter gravity sewer system conveys settled wastewater to its outlet by utilizing the difference in elevation between its upstream connections and its downstream terminus. It must be set deep enough to receive flows by gravity from the majority of the service connections and have sufficient capacity to carry the expected peak flows. Therefore, design decisions regarding its location, depth, size and gradient must be carefully made to hold the hydraulic losses within the limits of available hydraulic head energy. Where the differences in elevation are insufficient to permit gravity flow from an individual connection, energy must be added to the system by a lift pump (see Chapter 2). The number and location of individual lift stations or STEP units are usually determined from comparisons of their costs of construction, operation and maintenance with the cost of construction and maintenance of deeper and/or larger diameter (smaller headloss) sewers. The hybridization of SDGS with STEP is common.

4.3.1.1 Design Flow Estimates

The hydraulic design of sewer mains is based on the estimated flows which the sewer must carry. Since wastewater flows vary throughout the day, the sewer main must be designed to carry the expected prolonged peak flows, typically the peak hour flow. Conventional sewer design assumes 380 L//cap/d (100 gpcd) times a typical peaking factor of 4 for collector mains. This estimate includes allowances for commercial flows and infiltration. However, experience with SDGS has shown that these design flow estimates greatly exceed actual

Figure 4-3. Service lateral installation using a trenching machine.

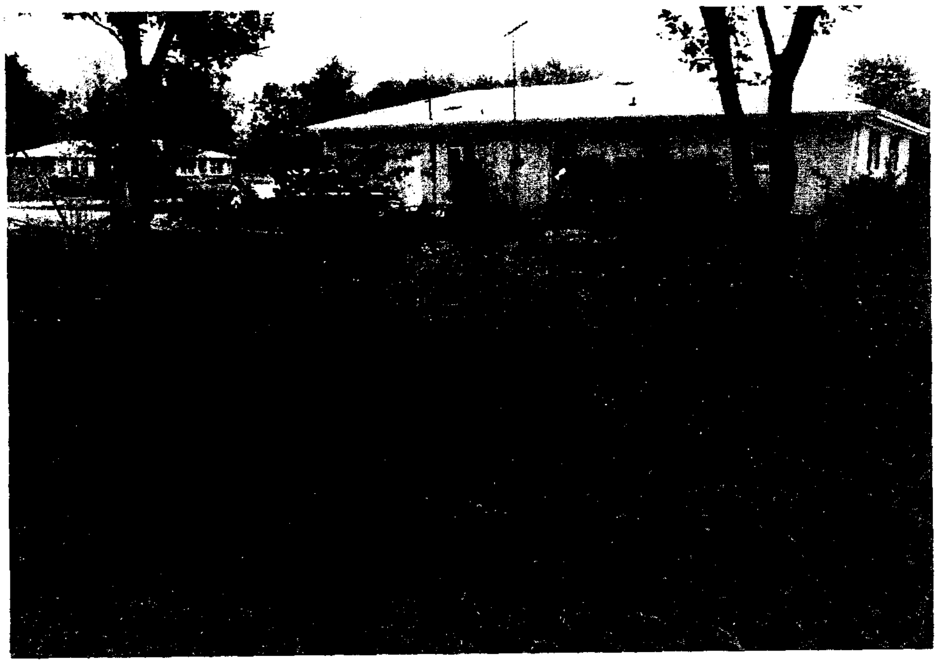


Figure 4-4. Typical combination cleanout and air release valve detail.

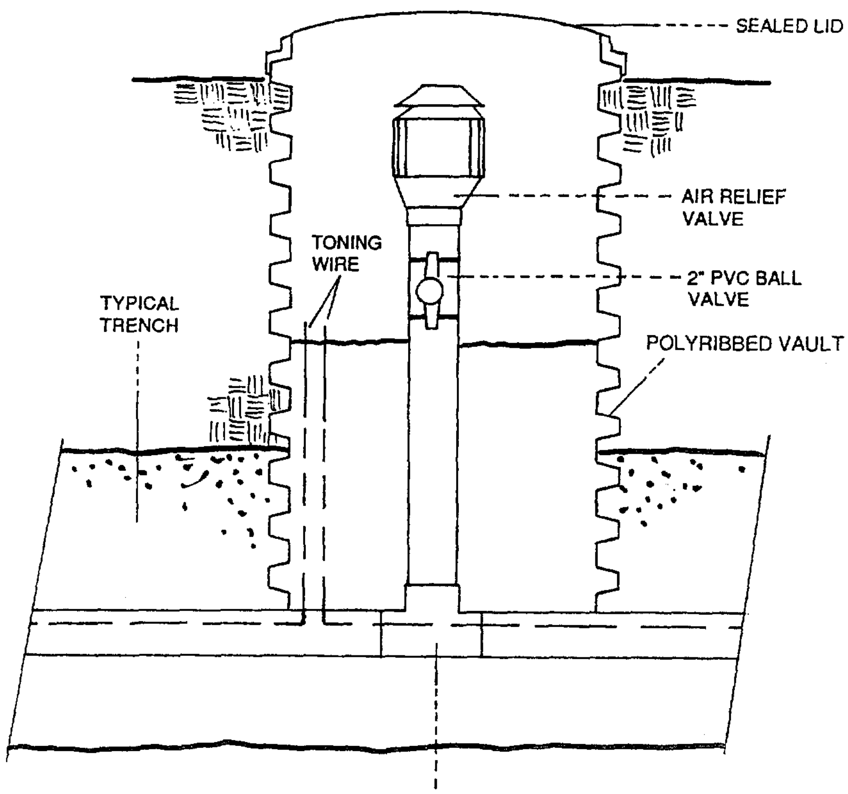
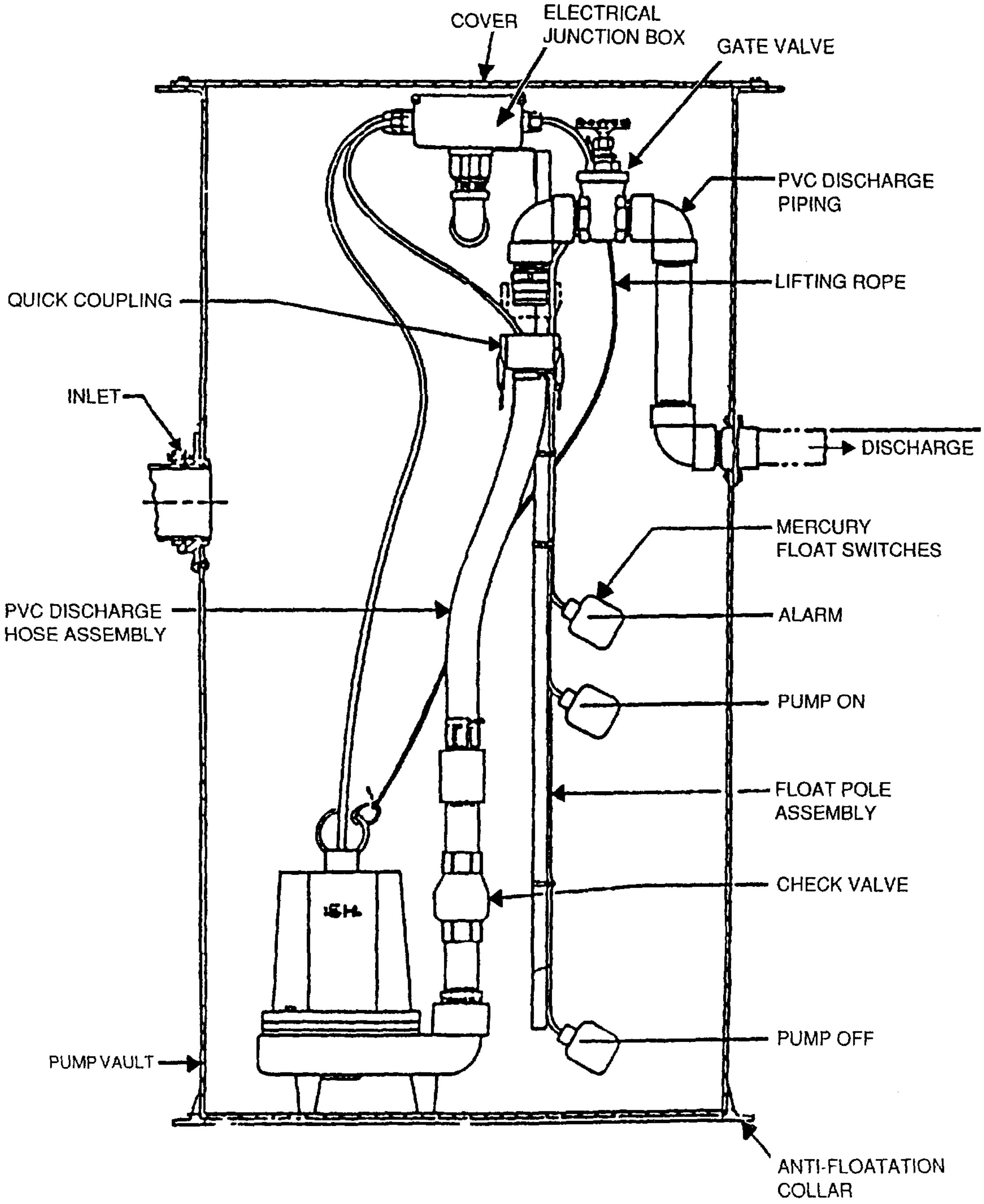


Figure 4-5. **Typical STEP lift station detail.**



flows because most SDGS serve residential areas where daily per capita flows are far less than 380 L/cap/d (100 gpcd); the peak to average flow ratio is also less than 4 because the interceptor tanks attenuate peak flows markedly.[2]

Measured average daily wastewater flow per capita is approximately 170 L/d (45 gpd).[3-5] However, in small communities and residential developments where little commercial or industrial activity exists, average per capita wastewater flows in sewers may be as much as 25 percent less.[6] Household wastewater flow can vary considerably between homes but it is usually less than 227 L/d (60 gpd) and seldom exceeds 284 L/cap/d (75 gpcd).[7] Typically, 190 L/cap/d (50 gpcd) is assumed for wastewater flows in residential areas where actual water use data are not available. Commercial flows are estimated individually using established criteria.[7]

The collector mains are sized to carry the maximum daily peak flows rather than the average flow. In residential dwellings, the rate of wastewater discharged from the building depends on its water use appliances and fixtures used. Instantaneous peak flows are typically 0.3-0.6 L/s (5-10 gpm).[7] Maximum flows of 0.1 L/s (1.7 gpm) may occur.[8,9] However, the interceptor tank in SDGS systems attenuates these peaks dramatically. Monitoring of individual interceptor tanks shows that outlet flows seldom exceeded 0.06 L/s (1 gpm) and most peaks ranged between 0.03 and 0.06 L/s (0.5-0.9 gpm) over periods of 30-60 minutes. There were long periods of zero flow.[2] The degree of attenuation depends on the design of the interceptor tank and/or its outlet.

In addition to wastewater flows, allowance must be made for potential clear water infiltration/inflow (I/I). Common sources of infiltration in SDGS systems are the building sewer and interceptor tank. In SDGS systems in which the existing septic tanks were used as interceptor tanks, wet weather flows have been significantly higher than dry weather flows. Leaking building sewers, cracked tanks and poorly fitting tank covers are the most common sources of infiltration. Where all new tanks were installed and the building sewers tested or replaced, the ratio of wet weather to dry weather flows have been much lower.[2]

In all systems, foundation drains and roof leaders may be significant sources of inflow and SDGS projects should attempt to eliminate them during construction. Despite these attempts, the designer may wish to allow for some degree of unavoidable I/I; but this allowance should be significantly lower than typical conventional gravity systems due to their higher elevation and smaller diameter.

Experience with SDGS systems has shown that the criteria used to estimate design flows have been conservatively high. Design flows have generally been 190-380 L/capita/d (50-100 gpcd) with peaking factors of 1 to 4. More recent designs have been based on flows per connection of 545-1,635 L/d (0.1-0.3 gpm). These design flow estimates have been successful because the interceptor tanks have storage available above the normal water level to store household flows for short peak flow periods.

4.3.1.2 Flow Velocities

Conventional sewer design is based on achieving "self-cleansing" velocities during normal daily peak flow periods to transport any grit which may enter the sewer, scour grease and resuspend solids that have settled in the sewer during low flow periods. However, in SDGS systems, the primary treatment provided in the interceptor tanks upstream of each connection remove grit, and most grease and settleable solids. Studies have shown that the remaining solids which enter the collectors and any slime growths which develop within the sewer are easily carried when flow velocities of 15 cm/s (0.5 fps) are achieved.[2]

Experience with SDGS has shown that the normal flows which occur within the systems are able to keep the mains free-flowing. Thus, SDGS need not be designed to maintain minimum flow velocities during peak flows although many state agencies require that minimum velocities of 30-45 cm/s (1.0-1.5 fps) be maintained during daily peak flow periods.

Maximum velocities should not exceed 4-5 m/s (13-16 fps). At flow velocities above this limit, air can be entrained in the wastewater that may gather in air pockets to reduce the hydraulic capacity of the collector. Drop cleanouts or manholes should be employed where the pipe gradient results in excessive velocities.

4.3.1.3 Hydraulic Equations

Hydraulic equations used for design of the sewer mains are the same as those used in conventional gravity sewers. However, unlike conventional gravity sewers, sections of SDGS systems are allowed to be depressed below the hydraulic grade line such that flows may alternate between open channel and pressure flow. Therefore, separate analyses must be made for each segment of the sewer in which the type of flow does not change.

Both Manning's and Hazen-Williams pipe flow formulas are used. Roughness coefficients used range from 0.009 to 0.015 for Manning's "n" and 100 to 150 for Hazen-Williams "C". Typical "n" and "C" values are 0.013 and

140 respectively.[2] Nomographs and hydraulic elements graphs may be found elsewhere.[10]

Design depths of flow allowed in the sewer mains have been either half-full or full. Most older systems designed with uniform gradients have used half-full conditions to dictate changes in pipe size. However, systems with variable gradients allow the collector main to be surcharged at capacity. In these systems, pipe size changes are dictated by the relative elevation of the hydraulic grade line to any service connection elevation.

Design procedures follow conventional sewer design except in sections where pressure flow occurs. In these sections, the elevation of the hydraulic grade during daily peak flow conditions must be determined to check that it is lower than any interceptor tank outlet invert. If not, free-flowing conditions will not be maintained at every connection. Where the hydraulic grade line is above a tank invert, the depth of the sewer can be increased to lower the hydraulic grade line, or the diameter of the main can be increased to reduce the frictional headloss or a STEP unit can be installed at the affected connection to lift the wastewater into the collector. If short term surcharging above any interceptor tank outlet inverts is expected, check valves on the individual service lateral may suffice to prevent backflow.

4.3.2 Collector Mains

4.3.2.1 Layout

The layout of SDGS is a dendriform or branched system similar to that of conventional sewers except that the mains are usually not laid down the street center line so that expensive pavement restoration is avoided. In most cases, SDGS are located alongside of the pavement in the street right-of-way. If there are numerous services on both sides of the street, collectors may be provided on both sides to eliminate pavement crossings. Another alternative is to locate the collectors down the back property lines to serve a whole block with one collector. The backlot alternative may be the most accessible to homeowners since most septic tank systems are located in the backyard. Therefore, homeowners are not required to reroute the building sewer to the front of the lot, but access for interceptor maintenance may be limited. Since new interceptor tanks are usually installed, SDGS are installed most often in the front of the lots. If necessary, the building drains are redirected to the front.

4.3.2.2 Alignment and Grade

The horizontal alignment of SDGS need not be straight. Obvious obstacles such as utilities, large trees, rock outcrops, etc. should be avoided with careful planning, but unforeseen obstacles can often be avoided by bending the pipe. The radius of the bend should not exceed that recommended by the pipe manufacturer for the conditions under which it is to be installed.

The gradient of SDGS must provide an overall fall sufficient to carry the estimated daily hourly peak flows, but the vertical alignment need not be uniform. Inflective gradients, where sections of the main are depressed below the static hydraulic grade line, are permissible if the invert elevation is controlled where the flow in the pipe changes from pressure to open channel flow. The elevation of these summits must be established such that the hydraulic grade line does not rise above any upstream interceptor tank outlet invert during peak flow conditions. Adequate venting must also be provided at the summit. Between these critical summits, the profile of the sewer should be reasonably uniform so unvented air pockets do not form which could create unanticipated headlosses in the conduit and excessive upstream surcharging.

4.3.2.3 Pipe Diameter

The pipe diameter is determined through hydraulic analysis. It varies according the to the number of connections and the available slope. The minimum diameter used is typically 10 cm (4 in), but 5-cm (2-in) diameter pipe has been used successfully in recent projects. Where the 5-cm (2-in) diameter pipe is used, the interceptor outlets have used flow control devices to limit peak flows, and check valves to prevent flooding of service connections during peak flow periods. The costs of the flow control devices and check valves generally cancel savings realized from the smaller pipe; 10-cm (4-in) diameter pipe, therefore, is most commonly used as a minimum size.

4.3.2.4 Depth

The depth of burial for the collector mains is determined by the elevation of the interceptor tank outlet invert elevations, frost depth or anticipated trench loadings. Any of these conditions may control. In most cases, designers do not attempt to set the depth such that all connections can drain by gravity. Where gravity drainage from a residential connection is not possible, STEP lift stations are used. An optimum depth is selected to minimize the total construction costs due to mainline excavation and the installation of STEP units. However, the depth must not be less than that sufficient to prevent damage from anticipated loadings. Where the pipe is not buried below pavement or subject to traffic loadings, the minimum depth is typically 75 cm (30 in); however, a depth of 60 cm (24 in) is considered minimum for conventional pipe. Pipe manufacturer should be consulted to determine the minimum depth recommended. In cold climate areas, the frost depth may determine the minimum depth of burial unless insulated pipe is used.

4.3.2.5 Pipe Materials

PVC plastic pipe is the most commonly used pipe material in SDGS systems. Standard dimension ratio (SDR) 35 is used in most applications, but SDR 26 may be specified for road crossings or where water lines are within 3 m (10 ft). For deep burial, SDR 21 may be necessary. Where the use of STEP units is anticipated, only SDR 26 or 21 should be used for the affected segment of collector mains because of pressurizing requirements and the compatibility of pipe fittings. Typically, elastomeric (rubber ring) joints are used, however, for pipe smaller than 7.5 cm (3 in) in diameter, only solvent weld joints may be available.

HDPE has been used infrequently, but successfully. Pipe joining is by heat fusion.

4.3.3 Service Laterals

Typical service laterals between the tank and the sewer line are 10-cm (4-in) diameter PVC pipe, although laterals as small as 3 cm (1-1/4 in) in diameter have been used; they are not recommended. The service lateral should be no larger than the diameter of the collector main to which it is connected. The connection is typically made with a wye or tee fitting. Where STEP units are used, wye fittings are preferred.

Occasionally, check valves are used on the service lateral upstream of the connection to the main to prevent backflooding of the service connection during peak flows. If used, it is important that the valve be located very close to the collector main connection. Air binding of the service lateral can occur if the valve is located near the interceptor tank outlet.

4.3.4 Interceptor Tanks

4.3.4.1 Location

The interceptor tanks should be located where they are easily accessible for periodic removal of accumulated solids. Typically, they serve a single home and are located near the house between the foundation and the collector main adjacent to or in place of the existing septic tank. Single tanks serving a group of homes have not been accepted by users because of fear of backups; therefore, tanks at each connection are recommended. If the collector main is located on the opposite side of the building, reversal of the building drainage may be desirable, but not necessary. Access for maintenance is the critical factor in location. In some projects, the tank has been located in the public right-of-way to eliminate the need for the utility district to enter private property to pump the tank (Figure 4-6).

4.3.4.2 Design

Prefabricated, single-compartment septic tanks are typically used for interceptor tanks in SDGS systems. Most projects standardize the use of 3,785-L (1,000-gal) tanks for all residential connections. For commercial establishments, local septic tank codes are commonly used to determine the necessary volume. For a given volume, several tank designs may be available locally. Shallow tanks, or tanks with the greater water surface area for a given volume are preferred designs because of the greater flow attenuation that they provide.

Inlet and outlet baffles are provided in conventional septic tanks to retain solids within the tank. These baffles are adequate for SDGS applications. The inlet baffle must be open at the top to allow venting of the interceptor tank through the building plumbing stack. On the outlet, various "gas deflection" baffles or outlet screens may be used to capture low density or neutral buoyancy solids that might otherwise pass through the tank (Figure 4-7). These devices are not necessary, however, since these solids have not been shown to cause problems in SDGS systems.

Flow control devices have been used on interceptor outlets to limit peak flow rates to a predetermined maximum. Surge chambers were added to interceptor tanks in early projects.[11] The surge chamber contained a standpipe with a small orifice drilled near the bottom (Figure 4-8). During peak flow periods, the chamber provides storage for the wastewater while the orifice controls the rate of flow from the tank. These chambers are no longer used because the orifices plug readily so the chambers are not effective in flow attenuation. They also require about 30-45 cm (1.0-1.5 ft) of headloss which may require deeper burial of the collectors and, as a result, higher construction costs. Also, odor problems have resulted due to the free fall of available interceptor tank effluent. Flow control devices are now available that are placed within the interceptor tank and use the freeboard provided in the tank for storage (Figure 4-9).

Water-tightness is a critical criterion in selection of an interceptor tank. For that reason, existing septic tanks are infrequently converted to interceptor tanks. Earlier systems attempted to use the existing septic tank at each home to reduce construction costs. It was found that septic tanks are difficult to inspect and repair properly. SDGS systems reviewed which had significant numbers of old tanks all had high ratios of wet weather to dry weather flows.[2] Common practice now is to replace all tanks. Currently, there is no standard procedure for existing tank leakage inspection. This practice has the added advantage of requiring the property owner to replace the building sewer to ensure greater

Figure 4-6. **Alternative locations for interceptor tanks.**

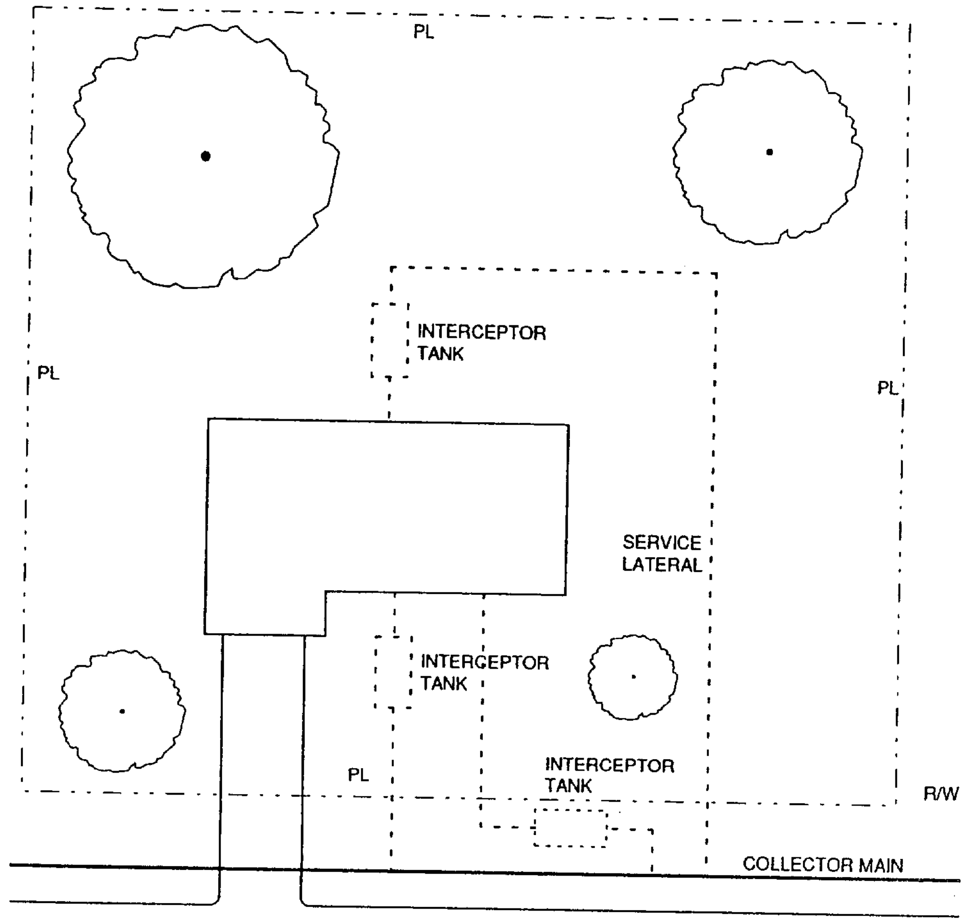


Figure 4-7. **Typical interceptor tank outlet baffles.**

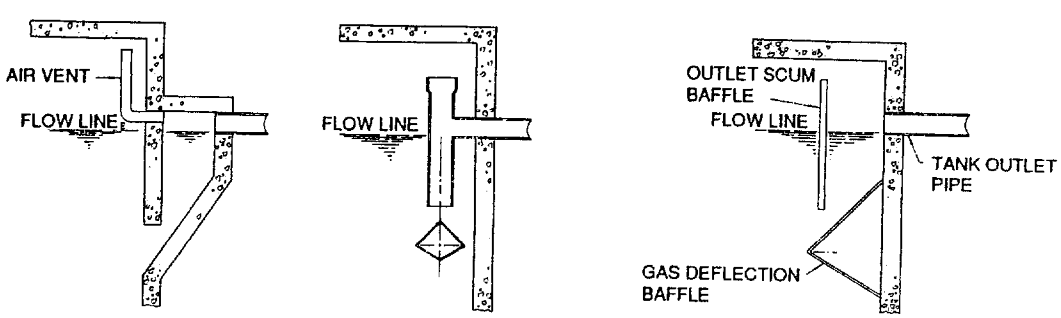


Figure 4-8. **Typical surge chamber detail. (Courtesy Orenco Systems)**

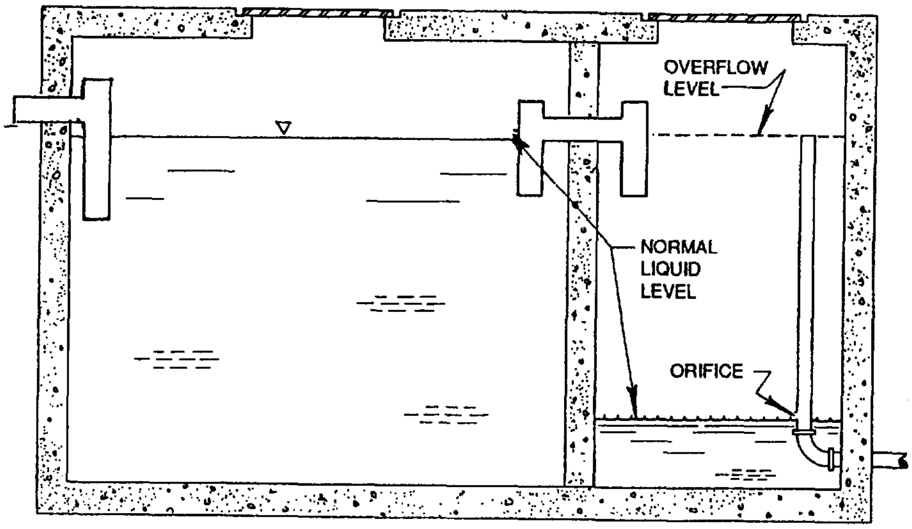
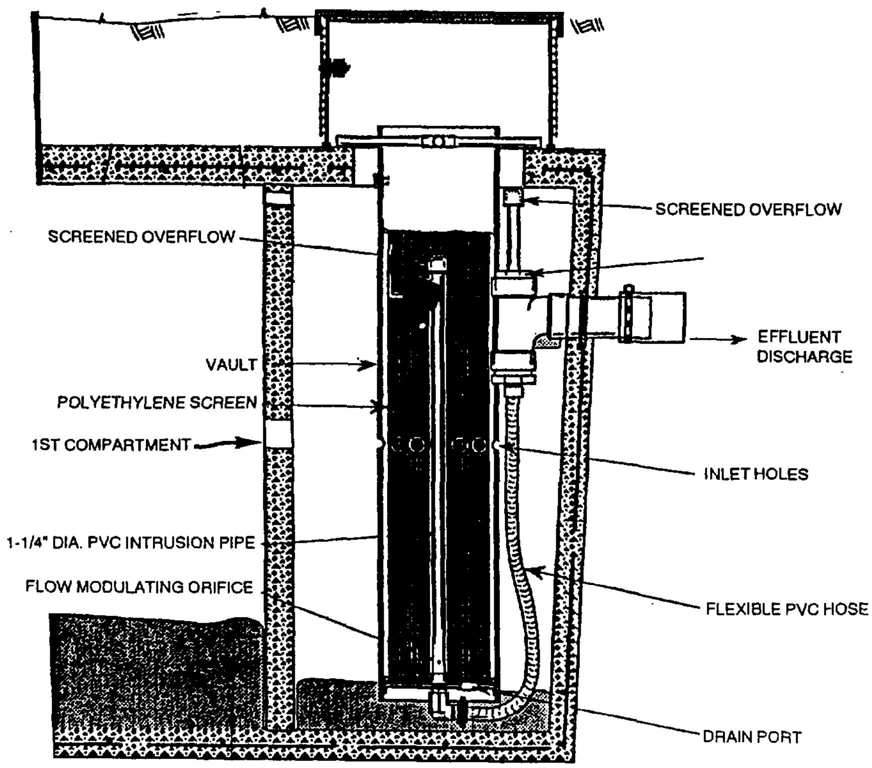


Figure 4-9. **Interceptor outlet flow control device.**



watertightness. Some projects incorporate the replacement of the building sewer to allow inspection of the building plumbing to eliminate roof leaders, foundation drains and other unwanted connections that contribute clear water inflow.

Access to the tank for periodic inspections and solids removal is required. A sufficiently large opening over the tank inlet or outlet to allow inspection and effective sludge removal should be provided. However, because of the tank's septic conditions, unsupervised or unaccompanied personnel must not enter the tank. All applicable safety codes must be followed in the design of these facilities. The opening should be a minimum of 45-cm (18-in) square or in diameter. A watertight riser terminating 15 cm (6 in) above grade with a bolted or locking air tight cover is preferred to a buried access.

4.3.4.3 Material

Prefabricated septic tanks are typically used for interceptor tanks. They are available in reinforced concrete, coated steel, fiberglass and high density polyethylene. Unfortunately, the quality of manufacture varies from locality to locality. Therefore, it is necessary to carefully inspect and test random tanks for structural soundness for the intended application and for watertightness. Coated steel tanks are not recommended because the coating is easily damaged during storage and installation, leading to severe corrosion and short tank life.

All tank joints must be designed to be watertight. The joints include tank covers, manhole risers and covers and inlet and outlet connections. Rubber gasket joints for inlet and outlet connections are preferred to provide some flexibility in case of tank settlement.

4.3.5 Manholes and Cleanouts

In most SDGS systems, cleanouts are used instead of manholes, except at major junctions at mains. Since hydraulic flushing is all that is necessary to maintain the mains in a free-flowing condition, cleanouts provide sufficient access to the mains. Cleanouts are less costly to install than manholes and are not a source of infiltration, inflow or grit. Since the SDGS system is not designed to carry grit, elimination of manholes is strongly recommended. Manholes represent a potential source of odors and of grit and other solids in SDGS systems.

Cleanouts are typically located at upstream termini of mains, junctions of mains, changes in main diameter and at intervals of 120-300 m (400-1,000 ft) (Figure 4-10). Cleanouts may also be used in place of drop manholes. The cleanouts are typically extended to ground surface within valve boxes.

Manholes, if used, are located only at major junctions. The interiors should be coated with epoxy or other chemical resistant coating to prevent corrosion of the concrete. The covers used are typically gas-tight covers to limit the egress of odors and inflow of clear water.

Where depressed sections occur, the sewer must be well vented. Cleanouts may be combined with air relief valves at high points in the mains (Figure 4-4) or an open vent cleanout installed (Figure 4-11).

4.3.6 Valves

Air release, combination air release/vacuum and check valves may be used in SDGS systems. Air release and combination air release/vacuum valves are used for air venting at summits in mains that have inflective gradients in lieu of other methods of venting. These valves must be designed for wastewater applications with working mechanisms made of type 316 stainless steel or of a plastic proven to be suitable. The valves are installed within meter or valve boxes set flush to grade and covered with a water tight lid (Figure 4-4). If odors are detected from the valve boxes, the boxes may be vented into a small buried gravel trench beside the boxes (see Section 2.4.8).

Check valves are sometimes used on the service connections at the point of connection to the main to prevent backflow during surcharged conditions. They have been used primarily in systems with 5-cm (2-in) diameter mains. Many types of check valves are manufactured, but those with large, unobstructed passageways and resilient seats have performed best. Wye pattern swing check valves are preferred over tee pattern valves when installed horizontally. Although the systems with 10-cm (4-in) diameter mains have operated well without check valves, their use can provide an inexpensive factor of safety for these applications as well. An alternative method used to prevent pumping backups in some projects has been to provide an interceptor tank overflow pipe to the drain field of the abandoned septic tank system. Care must be exercised to prevent backflow through such connections in areas with high groundwater. In Australia, a "boundary trap" is included at every connection which provides an overflow to the ground surface if backups occur (Figure 4-12).[12]

4.3.7 Odors and Corrosion

Odors are a commonly reported problem with SDGS systems. The settled wastewater collected by SDGS is septic and therefore contains dissolved hydrogen sulfide and other malodorous gases. These gases tend to be released to the atmosphere in quantity where turbulent conditions occur such as in lift stations, drop cleanouts or hydraulic jumps which occur at rapid and large changes

Figure 4-10a. Typical cleanout detail.

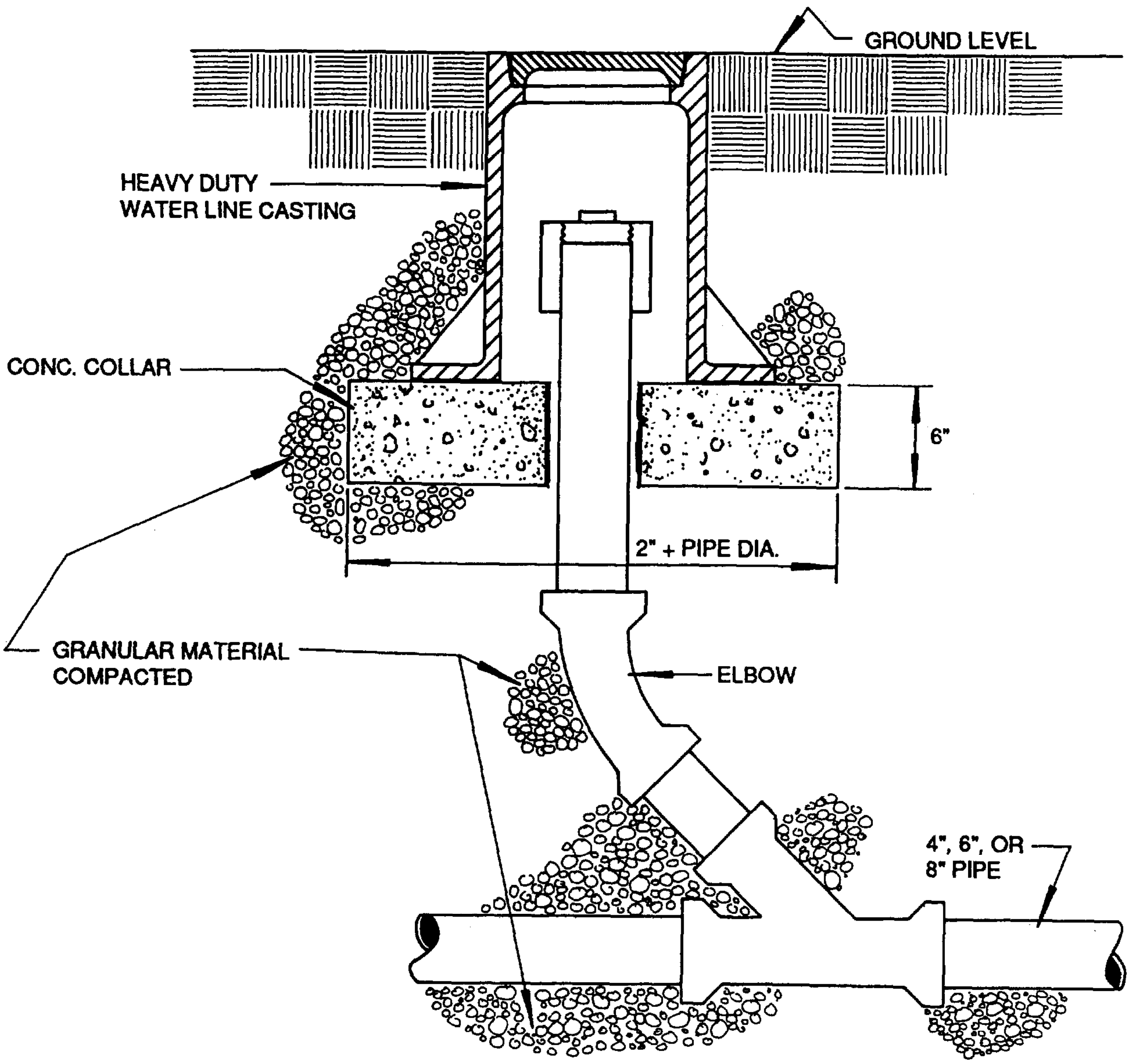


Figure 4-10b. **Typical cleanout detail.**

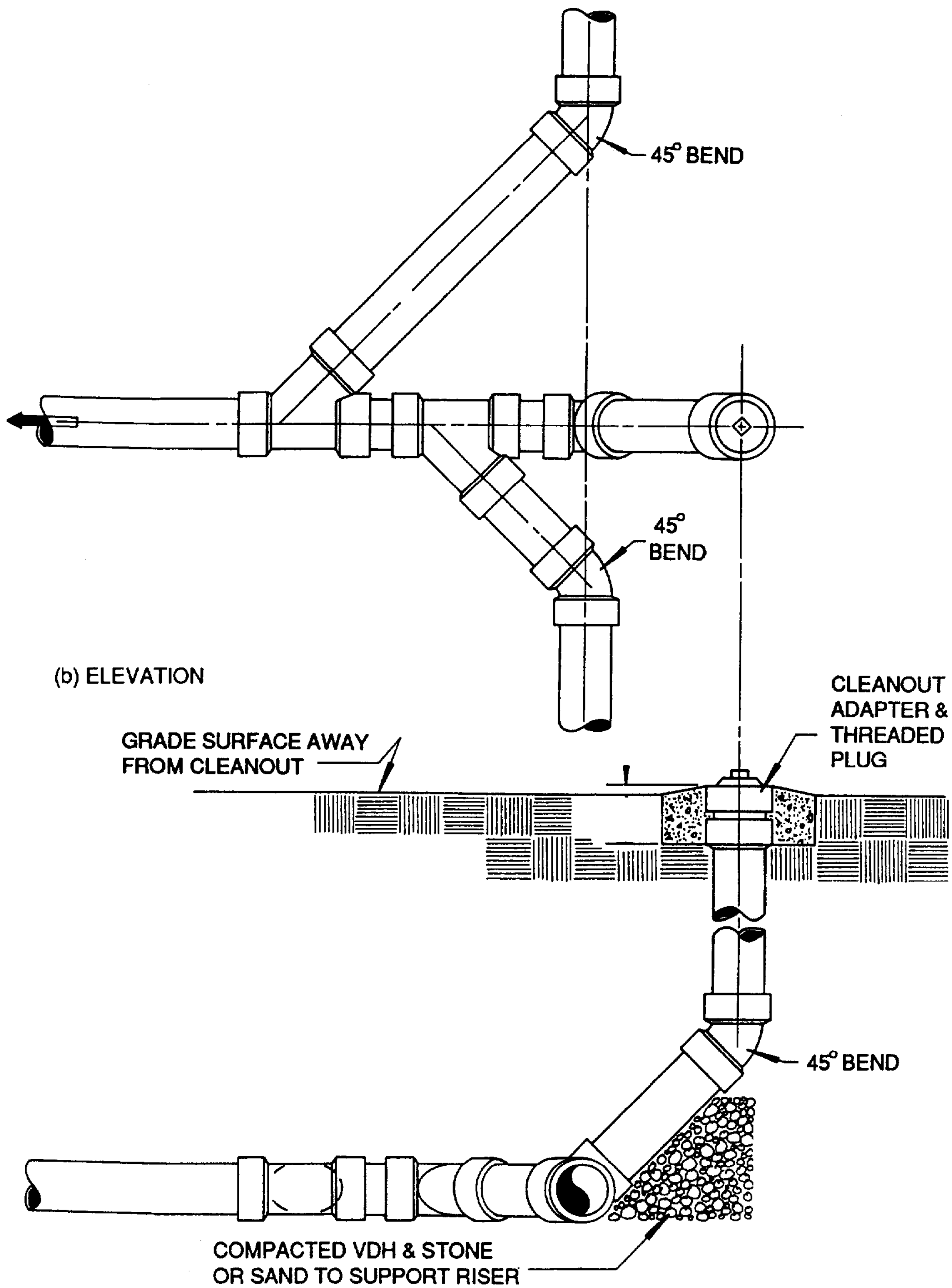


Figure 4-11. Ventilated cleanout detail.

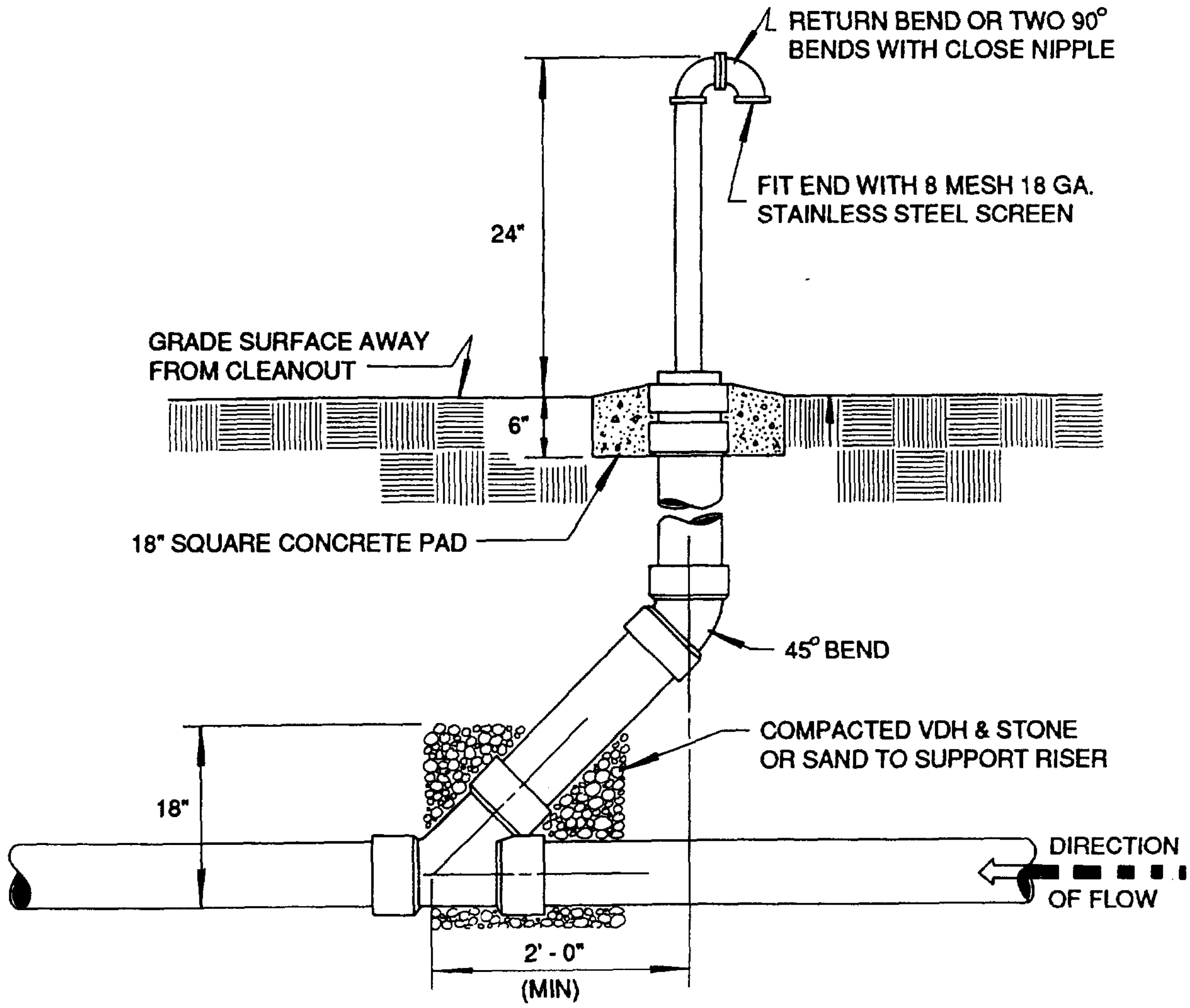
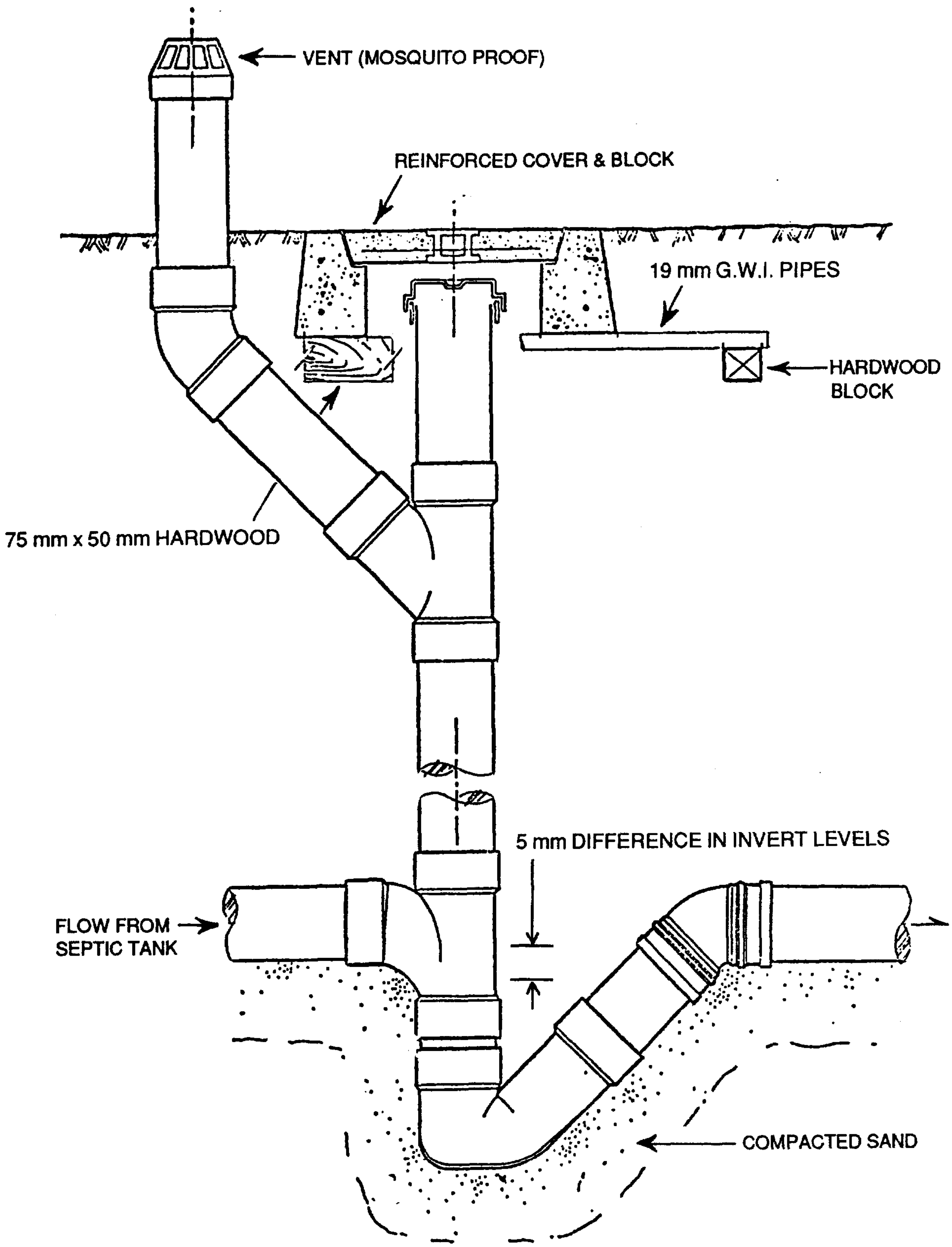


Figure 4-12. Australian boundary trap detail.



of grade or direction in the collector main. The odors escape primarily from the house plumbing stack vents, manholes or wet well covers of lift stations.

The odors have been controlled by minimizing turbulence and sealing uncontrolled air outlets. Drop inlets have been effective in eliminating odors at lift stations (Figure 4-13). Gas-tight lift station covers should be installed if odors are persistent and odor control provided for the fresh air vent. An effective odor control measure is to terminate the vent in a buried gravel trench (Figure 4-14). Carbon filters have been used successfully, but require regular maintenance. Manholes should be replaced with cleanouts; however,if used, the manholes should have gas-tight covers. Odors from improperly designed house plumbing vents have been controlled most easily by sealing the vent on top of the interceptor tank outlet tee or by installing water traps in the service lateral.

The atmosphere created by the released gases is very corrosive. Corrosion is a common problem in lift stations. Corrosion resistant materials must be used (see Section 2.4.8). More recent SDGS systems have used wet well/ dry well design for lift stations to reduce the exposure of mechanical components to the corrosive atmosphere.

4.4 Construction Considerations

4.4.1 General

Construction of small diameter gravity sewers is similar to construction of conventional gravity sewers except that strict horizontal and vertical control of main alignment is not required. As a result, construction can proceed much more quickly and be less costly. However, SDGS systems require that a significant portion of the work be performed on private property to install the interceptor tank and service lateral. Because the property owner can be very demanding in surface restoration, many general contractors are uncomfortable with such work. As a result, the bids received for construction may be few and inflated to account for the work on the service connections. To maximize the potential for cost savings, consideration should be given to letting two construction contracts, one to install the mains and the other to perform all work on private property. The contractor for the private work should be a contractor who is experienced in working with property owners such as a local septic tank system installer.

4.4.2 Mainline Construction

4.4.2.1 Line Changes

Setting the line of the collector main should be performed with the objective of minimizing site restoration costs. Detailed surveys during the design phase may not have been performed because of cost considerations. As a result, all obstacles in the intended path of the main may not have been identified on the plan sheets. Since straight alignment is not required for SDGS, changes in the alignment within maximum pipe deflection limits can be made in the field to avoid large trees, fences, pavement, etc. that could increase restoration costs. Most changes can be made by the construction manager, but major changes in alignment should be evaluated by the design engineer. Any changes made should be documented and shown on the as-built drawings.

4.4.2.2 Grade Control

Strict vertical control of SDGS during mainline construction is not necessary. In most cases, the pipe may be joined above ground and laid in the trench. However, the pipe should be laid as uniformly as is reasonable to minimize headlosses and potential points where gas can collect. If significant changes in the pipe profile are required to avoid utilities or at various crossings, they must be evaluated by the design engineer for air release valves. All changes must be documented and recorded on the as-built drawings.

4.4.2.3 Trench Construction

Trenching may be done by backhoe or trenching equipment. Over-excavation is not a critical concern if the change in the pipe invert elevation is not greater than one pipe diameter nor so sudden that the integrity of the pipe is threatened.

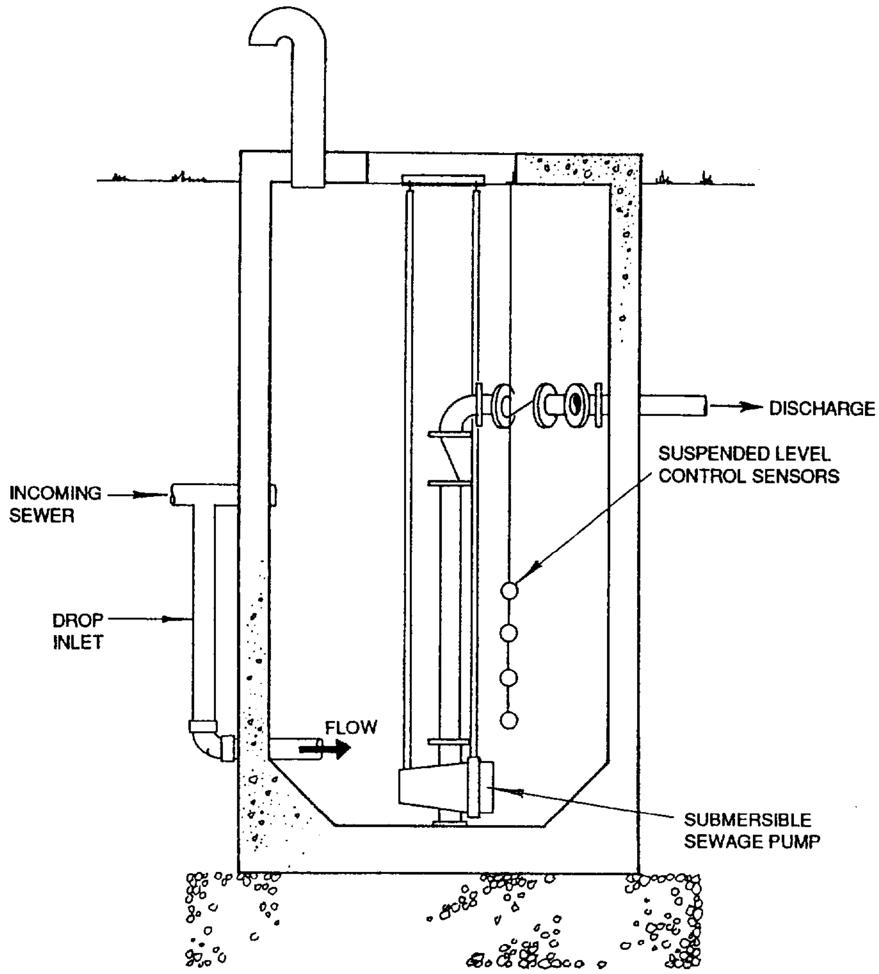
Select backfill for bedding and surrounding the pipe is necessary if the native trench spoil contains cobble or does not fill around the pipe snugly. Granular materials such as medium or coarse sand or pea gravel is usually used. Local requirements may control. To help locate the pipe or warn excavators working in the area, color coded warning tape should buried in the backfill 10-20 cm (4-8 in) below grade directly over the main. Pipeline markers which relate the pipe to existing permanent above ground structures should also be used.

4.4.3 Service Connections

Service connections include the building sewer, interceptor tank and service lateral to the collector main. Usually, the utility district is responsible for installation of the interceptor tank and service lateral while the user is responsible for installing the building sewer and its connection to the interceptor tank. However, in some cases, the utility district has also taken responsibility for installing the building sewer to help ensure a watertight connection and minimal inflow from illegal connections.

In laying out the service connection, the property owner should be involved. The owner should be consulted

Figure 4-13. Examples of drop inlets, external (a) and internal (b).



a) OUTSIDE DROP INLET

b) INSIDE DROP INLET

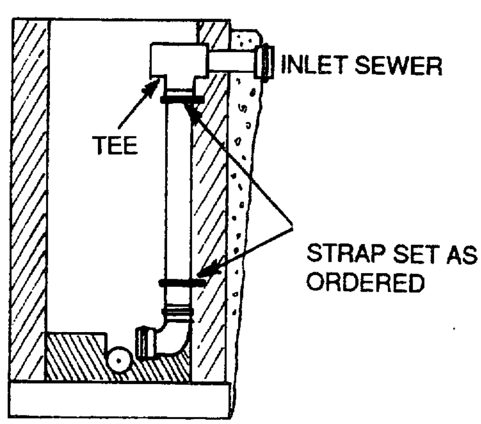
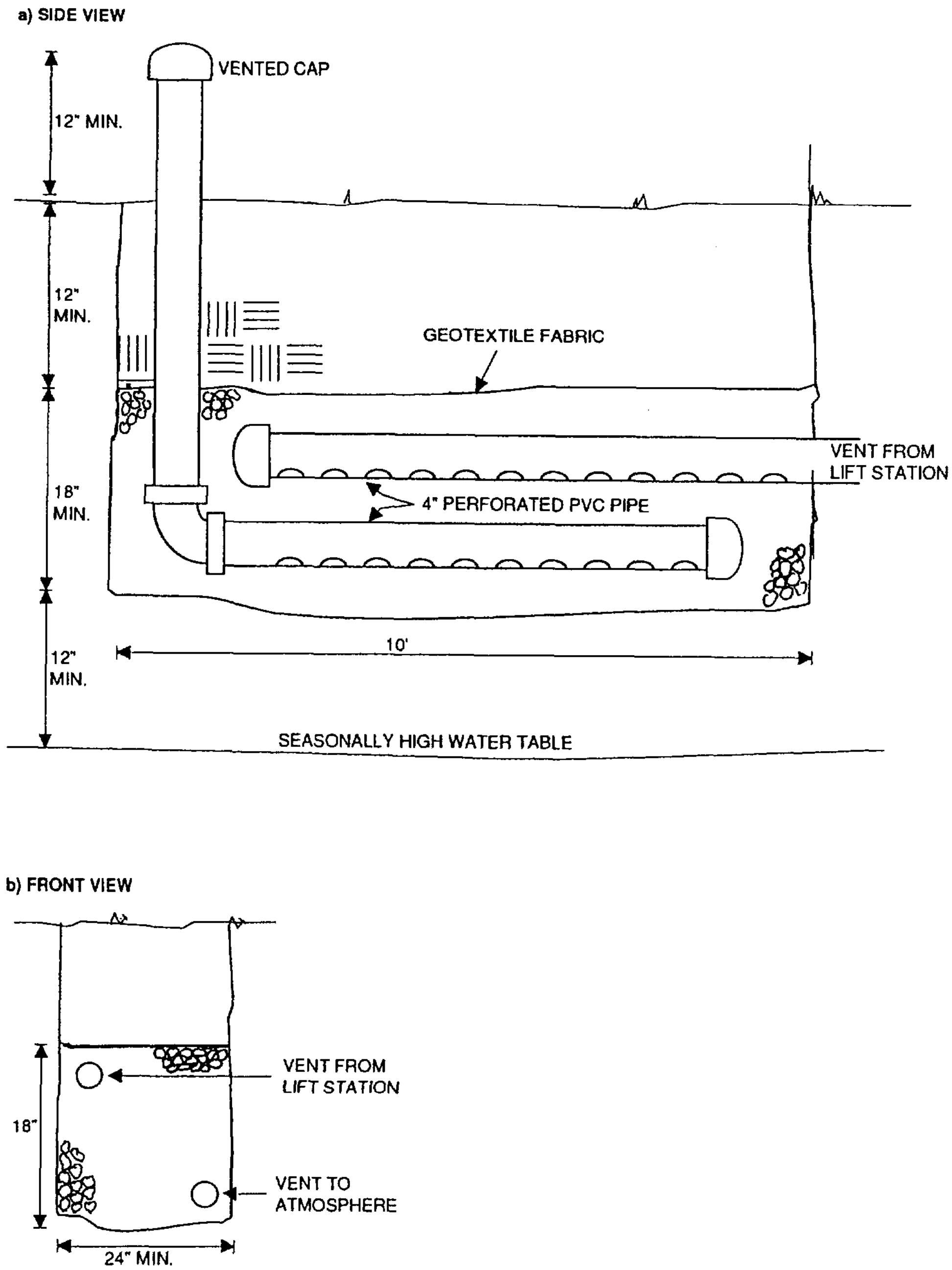


Figure 4-14. **Soil odor filter detail**



concerning the preferred location of the tank and service lateral, existing utilities and other areas of the property to be avoided. The proposed route and any areas to be affected by the construction activities should be video taped to provide a reference during restoration work.

Early SDGS systems attempted to utilize existing septic tanks at each connection as interceptor tanks to minimize construction costs. In such instances, the existing tanks were pumped and inspected prior to being accepted by the utility. However, where a significant number of existing tanks were included, clear water infiltration and inflow has been a problem. Current practice is to install all new interceptor tanks to limit infiltration and inflow. To provide the tightest system as possible, the user should be required to install a new building sewer subject to a leak test by the utility district. The existing tank must be pumped and abandoned by removal or by destruction and filling with inert solid material.

The interceptor tanks should be located where they can be reached easily for routine pumping by vacuum trucks. However, the tanks should be clear of any area subject to vehicular traffic. To facilitate maintenance, the interceptor tanks have been located in the public right-of-way in some projects. This approach avoids many of the problems associated with construction on private property, but does increase the hookup cost to the property owner since the owner is usually responsible for the building sewer to the interceptor tank.

Tank installation must follow the manufacturer's specifications. Proper bedding and flexible, water-tight inlet and outlet connections must be used. Flotation collars may be required to prevent flotation when the tank is pumped in areas that experience high water conditions.

As-built site plans should be prepared after the service connection is made. The plans should show the location of all elements of the service and referenced to permanent structures on-site. Where possible, photographs should be included in the record for the utility district.

4.4.4 Testing

Water-tightness testing of the collection mains, interceptor tanks, service connections and building sewers should be performed during construction. Testing procedures and criteria appropriate for conventional gravity sewers are used for testing the mains, service connections and building sewers. Both vacuum and hydrostatic tests are used for interceptor tanks. Typical acceptance criteria are less than 2.5 cm (1 in) loss of Hg vacuum after 5 minutes with an initial vacuum of 10 cm (4 in) of Hg or a drop in water level of 2.5 cm (1 in) after 24 hours in an overfilled tank. With the hydrostatic test, it is necessary that the tank be filled to at least 60 cm (2 ft) above the top of the tank to check covers and manhole riser connections. Typically, the property owner is responsible for testing of the building sewer to the satisfaction of the utility district before connection.

4.5 Operation and Maintenance Considerations

4.5.1 Administration

Utility or special purpose districts are commonly formed to administer, operate and maintain SDGS systems located outside municipal boundaries. These districts vary in structure and powers from state to state, but they typically have most of the powers of municipal government except for methods of generating revenues.

The sewer utility should be responsible for maintenance of the entire system. This includes all interceptor tanks and any appurtenances such as STEP units located on private property. Typically, the utility district assumes responsibility for all SDGS components downstream from the interceptor tank inlet. In some projects, the responsibility for maintenance of the components located on private property have been left to individual property owner. This avoids the need to enter private property. However, since the interceptor tank is critical to the proper performance of the SDGS system, responsibility for maintenance should be retained by the district. It is strongly recommended that the district assume ownership or equivalent responsibility for the interceptor tank and the components downstream of the tank to ensure access and timely appropriate maintenance.

To obtain access to the SDGS components located on private property, perpetual general easements are typically secured from the owner. The easements can take several forms, but general easements or easements by exhibit are recommended over metes and bounds easements because of the time and expense of writing metes and bounds. In some cases, the easements are obtained without compensation to the owner, while, in others, a nominal charge is provided. In all cases, property owners are entitled to some compensation under the Uniform Relocation act; but waiver thereof implies their support for the community's endeavor. Where it is necessary to cross private property with the collector mains, metes and bounds easements are usually used. An example of a general easement is presented in Figure 4-15

4.5.2 Operation and Maintenance Manual

An operation and maintenance manual is essential to every project. Although most maintenance tasks are relatively simple and usually do not involve mechanical

Figure 4-15. Example of general easement.

KNOW ALL MEN BY THESE PRESENTS:

That, in consideration of One Dollar and other good and valuable consideration paid to the undersigned respectively, hereinafter referred to as GRANTORS by the utility district, hereinafter referred to as GRANTEE, the receipt whereof is hereby acknowledged, the GRANTORS each, for their respective heirs, distributees, personal representatives, successors and assigns, do hereby grant, bargain, sell, transfer, convey, release, quit claim and remise unto the GRANTEE, its successors and assigns, a PERPETUAL EASEMENT to erect, construct, install, lay, use, operate, maintain, inspect, alter, clean, remove and replace sewer pipes, pumps, interceptor tanks and all appurtenances necessary and incident to the purposes of the easement, and, in connection with the same, temporarily to place machinery and materials which may be necessary to effect the purposes of the easement upon lands of the respective GRANTORS situate in the name of county and state TOGETHER WITH the right of ingress and egress over adjacent lands of GRANTORS, their respective heirs, distributees, personal representatives, successors and assigns, as the same may be required in order to effect the purposes of the easement. The location of the easement on the lands of each GRANTOR is respectively shown on Sheet No. __ of Contract No. __ for the contract drawings of the local entity, dated ______.

The GRANTEE expressly agrees that any and all disturbance to the surface of the lands of the GRANTOR will be promptly repaired and to the extent possible restored to their pre-existing condition, whether such disturbance takes place during the initial installation or at any time thereafter as may be occasioned by subsequent repairs or maintenance to the said sewer line and interceptor tank with the easement area.

Executed at the local entity on the respective dates as follows:

Date	Signature	Street Address	Tax Acct.

equipment, the manual does provide a valuable reference for location of components and services and typical drawings detailing the design and construction of each component. In addition, the manual should contain a comprehensive maintenance log to document all maintenance performed and any performance problems and the corrective actions taken. A good manual should contain, at a minimum, the following:

1. Description of the system
   A description of the system and each of its components should be provided. The component descriptions should include the function of each, their relation to adjacent components and typical performance characteristics. Specific design data, shop drawings, as-built plans and profiles of the collector mains and detailed plan drawings of each service connection are essential.

2. Description of the system operation
   Normal operation, emergency operation situations and procedures and failsafe features should be described.

3. System testing, inspection, and monitoring
   The purpose, methods, and schedule of all recommended testing, inspections and monitoring should be described. Sample recording forms should also be included.

4. Preventive maintenance procedures and schedules
   A clear description of all preventive maintenance procedures is needed with specific schedules for their performance.

5. Troubleshooting
   A description of common operating problems, how they may be diagnosed and procedures to correct them is extremely helpful to O&M personnel.

6. Safety
   Safety practices and precautions should be described to alert personnel to the potential hazards and methods to avoid or mitigate them. The dangers of working with septic wastes which generate dangerous hydrogen sulfide and methane gases must be emphasized.

7. Recordkeeping Logs and Forms
   Sample recordkeeping forms and logs should be provided.

8. Equipment Shop Drawings and Manuals
   Shop drawings and installation and maintenance manuals of all major equipment should be included.

Manufacturers and their suppliers should be listed with contact names, addresses and telephone numbers.

9. Utilities List
A list of all utilities in the project area, location maps and contact names, addresses and phone numbers should be provided.

10. System Drawings
Complete as-built drawings of the system are necessary. Detailed drawings of the service connections showing the precise location of all components with maintenance logs for each should be included.

4.5.3 Staff and Equipment Requirements

Operation and maintenance requirements of SDGS systems are generally simple in nature, requiring no special qualifications for maintenance staff other than familiarity with the system operation. The operator's responsibilities will be limited largely to service calls, new service connection inspections and administrative duties. In most systems, interceptor tank pumping is usually performed by an outside contractor under the direction of the utility district.

Maintenance equipment is also limited. A truck mounted centrifugal suction pump can be used to provide most emergency operation equipment needs. Sufficient hose should be purchased to reach between cleanouts. Other equipment can be provided by outside contractors as needed.

For STEP installations (including lift stations), O&M requirements are described in Section 2.6.

4.5.4 Operator Training

Specialized training for SDGS maintenance personnel is not necessary. Basic plumbing skills, however, are desirable. If a significant number of service connections include STEP units, an understanding of pumps and electrical controls is also helpful. (For a small number of such units, it is common for the utility district to retain local plumbing and electrical contractors to be available for any necessary repairs.)

The staff should be aware of the dangers of exposure to sewer gases and to avoid entry into confined spaces unless properly protected. Since a significant portion of the system is located on private property, it is important that the staff have good communication skills and a willingness to work with residents.

4.5.5 Spare Parts Inventory

Because SDGS systems have few mechanical parts, the need to maintain a spare parts inventory is limited. However, if individual STEP units are included in the system requiring that spare pumps and controls must be available for emergency repairs. A minimum of two spare pumps and the associated float switches and controls should be maintained for small systems (see Section 2.6.4 for further discussion). Pipe and pipe fittings should be kept on hand to repair any pipeline breaks that may occur. Spare interceptor lids and riser rings should also be kept.

4.5.6 As-Built Drawings

As-built drawings of the entire SDGS system including all on-lot facilities are essential to maintenance of the system. Curvilinear alignments and few manholes or cleanouts make locating the collector main routes difficult unless accurate drawings tying the location of the line to permanent structures are developed. As-built drawings of each individual service connection should also be made. These drawings are necessary when repairs are needed or when the components must be located to avoid damage due to other construction activities.

4.5.7 Maintenance

4.5.7.1 Normal

Normal maintenance is generally limited to call-outs by users. The call-outs are usually due to plumbing backups or to odors. In nearly every case reported, the plumbing backups were due to obstructions in the building sewer. Although the building sewer is the property owner's responsibility, most utilities have assisted the owner in clearing the obstruction. Odor complaints are common. As with the plumbing backups, faulty venting in the building plumbing is usually the cause. If improved venting fails to eliminate the odor complaints, the interceptor inlet vent can be sealed or running traps placed in the service lateral to prevent the sewer main from venting through the service connection.

4.5.7.2 Preventive

Preventive maintenance includes inspection and pumping of the interceptor tanks, inspection and cleaning of the collection mains and inspection and servicing of any STEP units or lift stations.

a. *Interceptor Tanks*

The interceptor tanks must be evacuated periodically to prevent solids from entering the collector mains. Prescribed pumping frequencies are typically 3-5 years, but operating experience indicates that a longer time between pumpings, of 7-10 years, is usually adequate (see Section 2.4.4). Restaurants and other high use facilities, such as taverns, require more frequent pumping. Common practice is to require additional grease removal and pump tanks serving these facilities every 6-12 months. Tank inspection is usually performed immediately after the tank has been evacuated to check for cracks, leaks, baffle integrity and general condition of the tank. If effluent screens are used on the tank outlet, they must be pulled and cleaned by flushing with water. Annual flushing of the screens is recommended if they are to be effective.

A preliminary septage handling and disposal plan must be developed which complies with existing State and Federal regulations. However, most utilities do not perform the pumping themselves. Private pumpers are usually hired through annual contracts to pump a designated number of tanks each year and to be on call for emergency pumping. The utility is responsible for the conduct of its contractors and must provide oversight to ensure compliance. The septage removed is usually land spread or discharged into a regional treatment plant.[13] During the pumping operations, utility district personnel should be present to record the depth of sludge and thickness of any scum in each tank so that the schedule can be altered according to actual accumulation rates.

b. Collector Mains

Periodic inspection and cleaning of the collector mains are the usually recommended maintenance functions. Hydraulic flushing is most often recommended for cleaning. Pressure hoses to push "pigs" through the mains have also been suggested as a cleaning method, but are not recommended if the collector mains are SDR 35 pipe. Reported performance of systems has been good and, therefore, inspection and flushing has not been deemed necessary by most utilities and has seldom been performed. In systems where the mains have been inspected, no noticeable solids accumulations have been noted. The experience with SDGS in Australia is similar. Many large systems there have been operating over 30 years without main cleaning. However, regular inspection and flushing is still recommended for long flat sections in which daily peak flow velocities are less than 15 cm/s (0.5 fps).

c. Lift Stations

Mainline lift stations should be inspected on a daily or weekly basis. Pump operation, alarms and switching functions should be checked and running times of the pumps recorded. The discharge rate of each pump should be calibrated annually.

4.5.7.3 Emergency Calls

Mainline or service lateral obstructions and lift station failures require that emergency actions be taken to limit the time the system is out of service to prevent environmental or property damage that might occur. It requires that the utilities have defined emergency operation procedures.

a. Obstructions

If an obstruction occurs, the utility must be able to respond quickly such that backups do not occur at upstream service connections. Experience has shown that most obstructions are caused by construction debris which cannot be removed by simple flushing. It may require that the main be excavated to remove the obstruction. While the obstruction is cleared, the utility must be prepared to pump from the cleanout, manhole or interceptor tank immediately above the obstruction to a cleanout or manhole below. A centrifugal suction pump or truck-mounted pump works well for this.

Fortunately, obstructions have been rare. All reported obstructions have occurred soon after construction or after an improperly inspected service connection was made. Construction debris has been the cause. Obstructions from other causes have not been reported.

b. Lift Stations

Lift stations may fail due to loss of power or a mechanical failure. Standby emergency generators can be provided for power during prolonged outages, but the generators can be costly and require regular maintenance. Because of the costs, many small communities have provided added storage at the lift station (Figure 4-16) and/or truck mounted pumps that can pump from the wet well to a downstream hose connection on the force main (Figure 4-17). This latter method also works well for mechanical failures.

4.5.8 Record Keeping

Good record keeping of all operation and maintenance duties performed is essential for preventive maintenance and trouble shooting when problems occur. A daily log should be kept and maintenance reports on all equipment filed. Flows at the mainline lift stations should be estimated daily by recording the pump running times. This is helpful in evaluating whether infiltration or inflow problems are developing. A record of each service call and corrective action taken should be filed by service connection identification number. This record should include tank inspection and pumping reports. These records are particularly useful if reviewed just prior to responding to a service call out.

4.5.9 Troubleshooting

4.5.9.1 Odors

Odors are the most frequently reported problem with SDGS systems. Odors typically occur at lift stations and

Figure 4-16. Mainline lift station with emergency storage.

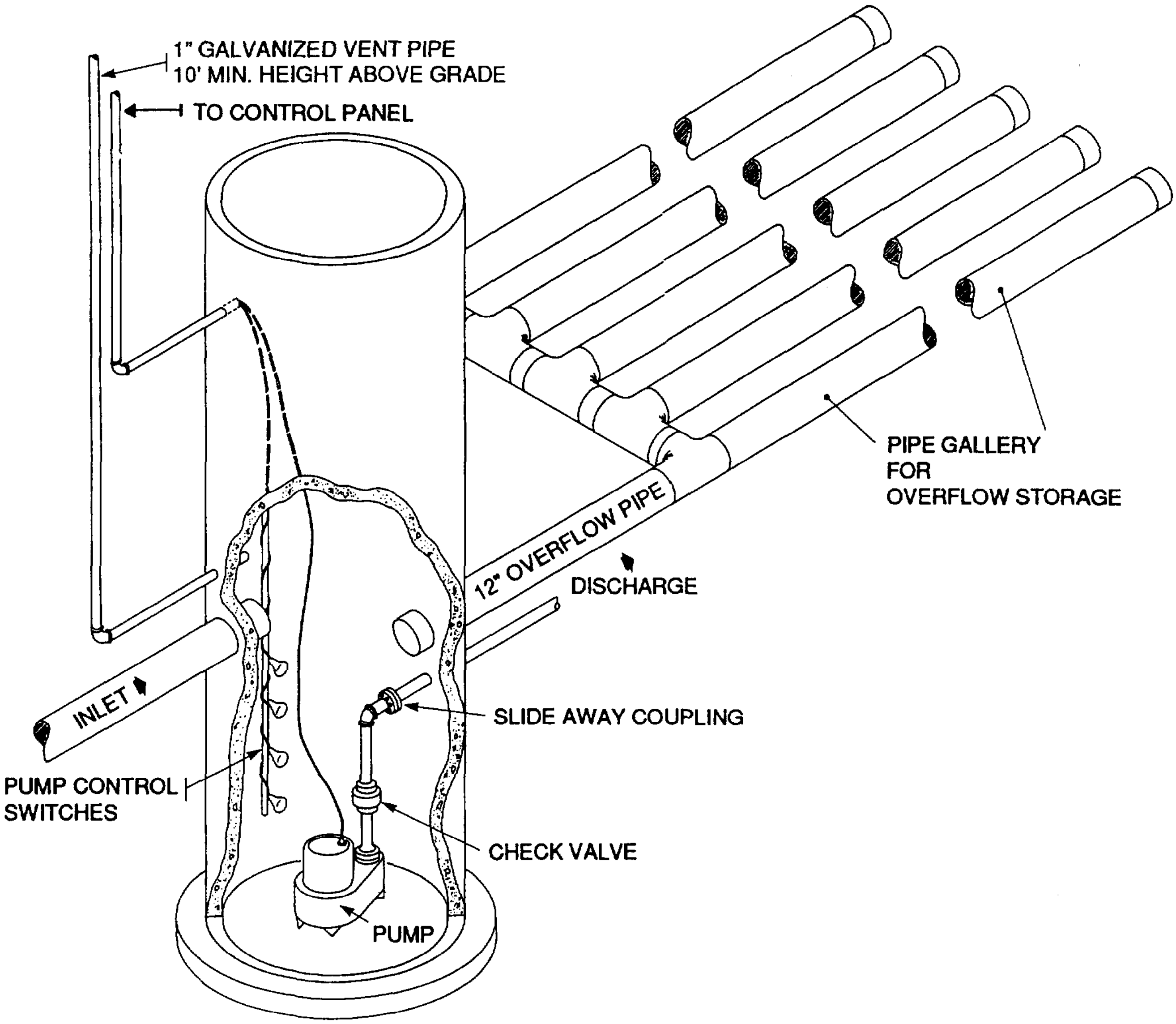
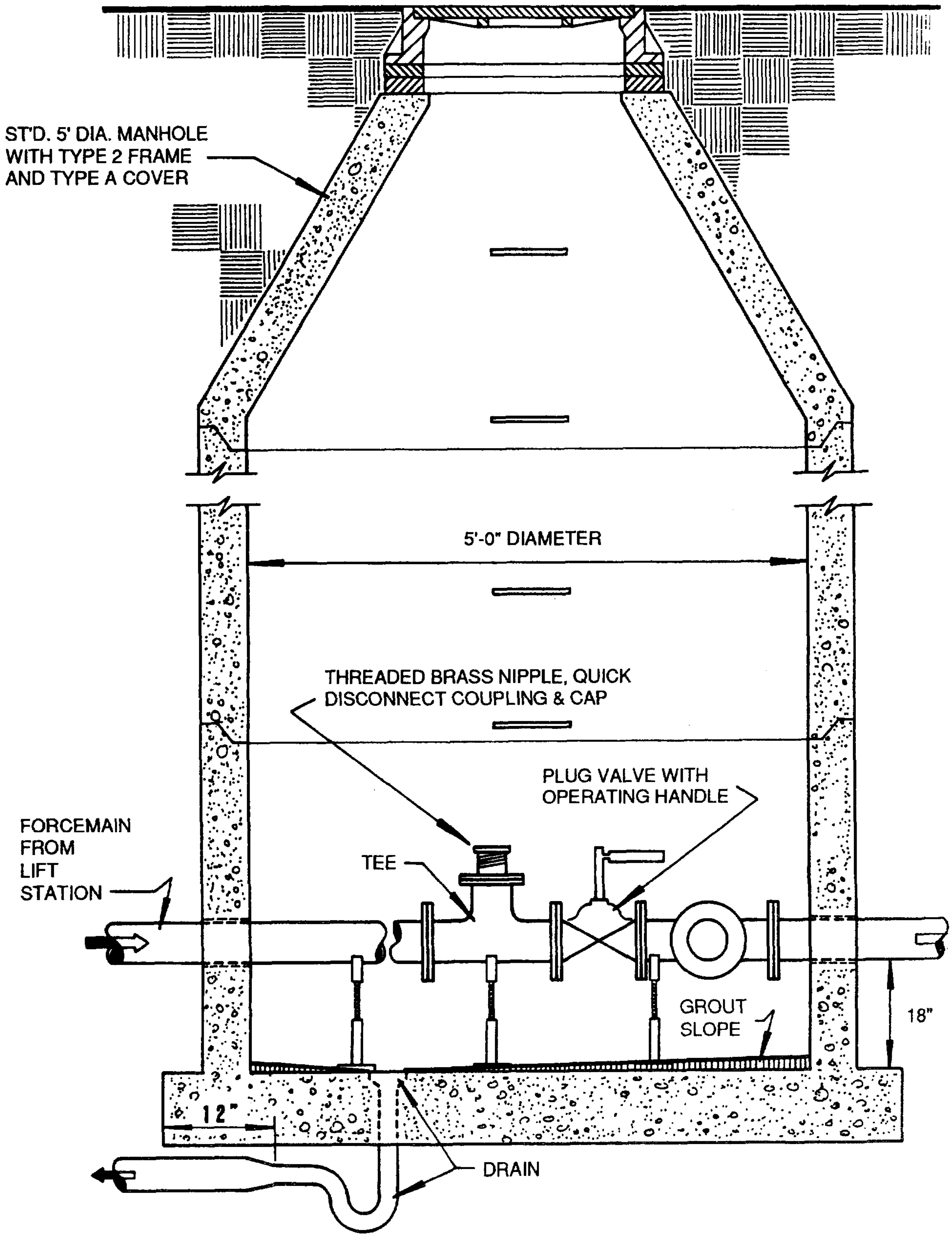


Figure 4-17. **Emergency pumping manhole.**



from house plumbing stack vents, particularly at homes located at higher elevations or ends of lines. Odors are most pronounced where turbulence occurs. The turbulence releases the obnoxious gases dissolved in the wastewater.

Odors at lift stations have been successfully eliminated by installing drop inlets that extend below the pump shut off level. This eliminates most of the turbulence. Other successful corrective measures include soil odor filters (Figure 4-14), air tight wet well covers and vents that extend 3-5 m (10-15 ft) above grade.

Odors at individual connections often originate in the collection main. If a sanitary tee or similar baffle device is used at the interceptor tank inlet or outlet, the top of the tee can be sealed or capped to prevent the gases escaping into the building sewer. P-traps or running traps on the service lateral have also been used (Figure 4-12). In some cases, extension of the main further upslope to where it can be terminated in a vented subsurface gravel trench has been employed successfully. The trench filters the odors before venting the gas to the atmosphere.

4.5.9.2 Corrosion

Corrosion is a problem that is usually most evident at lift stations and manholes. Nonferrous hardware must be used in lift station wet wells. Concrete manholes and wet wells must be coated with corrosion resistant materials. Alternatively, corrosion problems can be reduced in lift stations by using wet well/dry well construction with a well vented wet well.

4.5.9.3 Infiltration/Inflow

Clear water I/I was a common problem with earlier SDGS systems that used a high percentage of existing septic tanks for interceptor tanks. Leaking tanks or building sewers were the primary entry points of clear water. Systems that have installed all new interceptor tanks and pressure test building sewers and tanks have few I/I problems.

4.6 Review of Operating Systems

Because knowledge of the performance of operating small diameter sewer systems in the United States is relatively sparse, twelve operating systems were selected for review. The systems selected were based on size, date on-line, type of design (uniform grade versus variable grade), and local terrain. A summary of the projects selected for detailed review is presented in Table 4-1. Summaries of the interceptor tank and collector main designs are presented in Tables 4-2 and 4-3. Comparisons of system component use as a function of total feet of collector main installed are presented in Table 4-4.

All the systems reviewed have performed well. Obstructions have not occurred in any of the systems despite the fact that mainline flushing has not been performed. Odors have created nuisance problems in several systems, but control measures have been effective. Corrosion is a common problem in lift stations because the corrosive atmosphere created by the septic waste was not anticipated. In the systems where existing septic tanks and building sewers were retained, infiltration has been a significant problem. This has not been the case where new tanks and building sewers were installed.

Routine maintenance is limited to weekly inspection of mechanical equipment and pumping of the interceptor tanks every 5-7 years. Call outs have been infrequent and usually due to problems in the building sewer rather than the systems themselves.

4.7 System Costs

4.7.1 Construction

Construction costs were obtained from the twelve SDGS systems reviewed. Total construction costs adjusted to January, 1991 are presented in Table 4-5. Unit costs of components and their averages adjusted to January, 1991 are presented in Table 4-6. The costs of the components per foot of pipe installed and their adjusted averages for the various projects are presented in Table 4-7. Table 4-8 presents the component costs as a percent of the total construction costs.

Based on the costs from the twelve systems, the components were ranked from most to least costly:[2]

1. Collector mains
2. Interceptor tanks (including service lateral)
3. Mainline lift stations
4. Pavement restoration
5. Crossings (road, stream, utility)
6. STEP lift stations
7. Manholes
8. Site restoration
9. Force main
10. Miscellaneous

This ranking suggests in which areas efforts should be made in system design and construction to reduce the total costs.

Costs of installing the collector mains and the interceptor tanks and service laterals typically account for over 50 percent of the total cost of construction. The exact order of the other construction cost categories will depend on the characteristics of the individual project. Therefore,

Table 4-1. **Summary of SDGS Projects Reviewed**

Community	Pop.	Features	No. Connections	Length: Total (ft)	Length (%): 3-in	4-in	6-in	8-in	Pressure	Length/ Connection (ft)	Comments	Date On-Line
Mt. Andrew, AL	100	Gently sloping.	31	2,500	50 (3-in) 50 (2-in)	-	-	-	-	81	• Inflective gradient with sections depressed below HGL. • 2-in minimum diameter drains. • No manholes or cleanouts. • Some pressure inlets.	July 1975
Westboro, WI	200	Gently sloping. Deep well-drained soils.	87	18,846	-	77	-	5	18	217	• Uniform gradient. • Curvilinear alignment between manholes. • Hybrid gravity/pressure system.	Sept. 1977
Badger, SD	105	Flat to gently rolling.	53	6,616	-	77	23	-	-	125	• Uniform gradient.	Nov. 1980
Avery, ID	90	Narrow, steep-sided mountain valley bottom. Moderately deep soils.	55	6,690	-	100	-	-	-	122	• Uniform gradient. • No horizontal control maintained during construction. • Pipe gallery reserve storage in lift stations.	Sept. 1981
Maplewood, WI	150	Flat. Very shallow creviced bedrock.	61	5,800	-	-	100	-	-	95	• Uniform gradient • Emergency pump manholes below each lift station.	Nov. 1981
S. Corning, NY	2,000	Flat valley bottom. Steep side slopes. Poorly-drained soils.	606	45,525	-	77	23	-	-	70	• Uniform gradient. • "Sump manholes" isolate sections of network.	July 1983
New Castle, VA	190	Gently sloping. High seasonal water table. Bouldery soil.	64	6,955	-	64	-	36	-	109	• Uniform gradient.	May 1982
Miranda, CA	300	High, moderately to steeply sloping river terrace. Deep alluvial soils.	100	9,617	9	91	-	-	-	96	• Uniform gradient.	Nov. 1982
Gardiner, NY	500	Gently sloping.	109	19,330	-	71	19	10	-	177	• Uniform gradient. • Curvilinear alignment between manholes and cleanouts.	Dec. 1982
Lafayette, TN	1,500	Top of plateau and steep side slopes.	510	45,310	-	47	53	-	-	89	• Uniform gradient. • Curvilinear alignment between manholes and cleanouts. • Aerated lift stations for odor control.	Sept. 1983

Table 4-1. Summary of SDGS Projects Reviewed (continued)

Community	Pop.	Features	No. Connections	Total (ft)	Length (%) 3-in	4-in	6-in	8-in	Pressure	Length/ Connection (ft)	Comments	Date On-Line
West Point, CA	430	Very hilly with steep slopes. Shallow bedrock.	155	18,000	100 (2-in)	-	-	-	-	116	• Inflective gradient with sections depressed below HGL. • 2-in minimum diameter mains.	Nov. 1985
Zanesville, OH	1,880	Very hilly with steep slopes. Shallow bedrock.	711	61,362	18 (2-in) 10 (3-in)	2	-	-	70	86	• Buried at constant depth, but no sections depressed below HGL. • 2-in minimum diameter mains.	Oct. 1986
Muskingham Co., OH	2,150	Very hilly with steep slopes. Shallow bedrock.	767	89,748	79 (2-in) 16 (3-in)	3	2	-	-	117	• Inflective gradient with sections • 2-in minimum diameter mains. • Surge tanks installed following interceptor tanks.	Nov. 1986

Table 4-2. **Summary of Interceptor Tank Characteristics Used in Selected Projects**

Community	Sizing Criteria	Min. Size (gal)	Access	Special Features	Replacement Rate (%) Estimated	Actual
Mt. Andrew, AL	508-gal tank for all connections.	508	• Buried manhole	• Precast concrete • Outlet consists of 6 2-in clarifier tubes @ 60 degrees	100	100
Westboro, WI	Wisconsin Administrative Code	1,000	• Buried manholes • 4-in inspection port to grade	• Precast concrete	90	95
Badger, SD	1,000-gal tank for all connections	1,000		• Precast concrete	25	50
Avery, ID	1,000-gal single residence 1,500-gal double residence	1,000	• Buried manhole • 6-in inspection port to grade	• Precast concrete • Double layer mastic on risers	100	100
Maplewood, WI	Wisconsin Administrative Code	1,000	• Buried manhole • 4-in inspection port to grade	• Precast concrete • Located near road to minimize length of connection	100	100
S. Corning, NY	1,000-gal tank for all connections	1,000	• Buried manhole with O-ring gaskets • 4-in inspection port to grade	• Precast concrete with waterproof coating • Wall baffles with horizontal tee section on outlet • 2 outlets: upper one to existing dry well to act as overflow	75	83
New Castle, VA	2.5-day detention time based on metered flow	1,000	• Buried manhole • 6-in inspection port to grade	• Precast concrete	46	58
Miranda, CA	2-day detention time based on metered flow	750	• Manhole to grade	• Fiberglass tanks <1,500-gal capacity • Precast concrete 2-chambers >1,500-gal capacity • Coated and water tested • Structural specification	75	90
Gardiner, NY	New York Administrative Code	750	• Buried manhole • 4-in inspection port to grade	• Precast concrete • Structural specification	65	20
Lafayette, TN	Tennessee Administrative Code	750	• Buried manhole	• Precast concrete	5	23
West Point, CA	1,000-gal tank for all residential appllications	1,000	• Manhole to grade	• High-density polyethylene • Screened outlet • Flow controlled outlet	100	100
Zanesville OH	1,000-gal tank for all applications	1,000	• Manhole to grade	• High-density polyethylene • Spherical shape • 2-in diameter outlet • Gas deflection baffle	100	100
Muskingham Co., OH	1,000-gal tank for all applications	1,000	• Manhole to grade	• High-density polyethylene or concrete • 2-in diameter outlet • Separate surge tank	-	60

Table 4-3. Summary of Collector Main Design Criteria Used in Selected projects

Community	Design Flow	Min. Pipe Diameter (in)	Min. Design Velocity (fps)	Minimum Slope (%) 3-in	4-in	6-in	8-in	Roughness* Coefficient	Pipe Material	Alignment	Depth (ft) Min.	Avg.
Mt. Andrew, AL	0.4 gpm/connection	2	N/A	Inflective gradients				C = 150	PVC SDR 26	Curvilinear	1	1
Westboro, WI	72 gpcd	4	1.5 (0.5 full)	-	0.67	-	0.67	n = 0.013	PVC SCH 40	Curvilinear	7	7.5
Badger, SD	50 gpcd, min. pipe size based on fixtures	4	1.0 (full)	-	0.60	0.28	0.19	n = 0.011	PVC SDR 35	Straight	5	7.5
Avery, ID	70 gpcd peaking factor = 3	4	1.5 (0.5 full)	-	0.40	-	-	n = 0.010	PVC SDR 35	Curvilinear in horiz. plane	5	5
Maplewood, WI	75 gpcd peaking factor = 4	6	1.5 (0.5 full)	-	-	0.27	-	n = 0.013	PVC SDR 35	Straight	6	6
S. Corning, NY	200 gpd/connection peaking factor = 4	4	1.5 (full)	-	0.40	0.20	0.15	n = 0.011 (Kutter's)	ABS & PVC SDR 35	Curvilinear	4.5	7
New Castle, VA	50 gpcd peaking factor = 4	4	1.0 (0.5 full)	-	0.50	0.50	-	n = 0.013	PVC SDR 35	Straight	3	5.5
Miranda, CA	175 gpd/connection peaking factor = 2	3	1.5 (0.5 full)	0.94	0.67	-	-	n = 0.013	PVC SDR 35	Straight	4	8
Gardiner, NY	80 gpcd peaking factor = 4	4	1.5 (0.5 full)	-	0.67	0.40	0.40	n = 0.013	PVC SDR 26	Curvilinear	4	7.5
Lafayette, TN	350 gpd/connection	4	1.0 (0.5 full)	-	0.36	0.36	-	C = 100	PVC SDR 35	Curvilinear	2.5	4
West Point, CA	225 gpd/connection peaking factor = 2	2	0	Inflective gradients				n = 0.012	PVC SDR 26	Curvilinear	3	3.5
Zanesville, OH	0.5 gpm/connection	2	0	Inflective gradients (constant buried depth)				C = 150	PVC SCH 40 & SDR 35	Curvilinear	3.5	3.5
Muskingham Co., OH	0.5 gpm/connection	2	0	Inflective gradients				C = 150	PVC SDR 35 & SDR 26	Curvilinear	4.5	4.5

* C = Hazen-Williams; n = Manning's (except as noted)

Table 4-4. **Comparison of System Component Use as a Function of Number of Connections or Feet of Collection Main Installed in Selected Projects**

Community	Category								
	Mainline	Service Laterals	Septic Tanks	Manholes	Cleanouts	Manholes & Cleanouts	Residential Lift Stations	Mainline Lift Stations	Force Main, ft
	Feet of Category/Connection			Feet of Main/Category					
Westboro, WI	217	217	0.90	571	-	571	1,450	5,143	8.2
Badger, SD	125	125	0.38	348	-	348	6,616	3,308	10.3
Avery, ID	122	122	1.02	3,345	394	352	-	1,673	2.4
Maplewood, WI	95	95	0.80	1,450	112	104	-	1,933	1.7
S. Corning, NY #1	63	63	0.88	3,096	310	281	3,715	-	-
S. Corning, NY #2	77	77	0.81	2,994	342	307	2,395	-	-
New Castle, VA	109	109	0.30	541	104	84	-	6,955	3.1
Miranda, CA	96	96	0.72	1,374	163	146	962	-	46.7
Gardiner, NY	177	98	0.94	716	805	379	2,761	19,330	6.6
Lafayette, TN	89	89	0.05	1,678	781	533	22,655	5,034	4.6
West Point, CA	116	94	1.03	-	857	857	-	18,000	3.6
Zanesville, OH	83	123	0.43	2,609	272	246	163	-	-
Average	114	109	0.67	1,702	414	351	5,090	7,672	9.3

Table 4-5. Comparison of SDGS Construction Costs ($) from Selected Projects

Community (Bid Date)	Construction Costs	Cost/Connection		Cost/ft of Main	
		Bid	Adjusted to January 1991	Bid	Adjusted to January 1991
Westboro, WI (Jan. 1977)	245,635	2,959	5,668	13.03	24.96
Badger, SD (July 1980)	103,281	1,949	2,856	15.61	22.87
Avery, ID (Aug 1980)	290,280	5,278	7,632	43.39	62.74
Maplewood, WI (Dec. 1980)	265,903	4,359	6,168	45.85	64.88
S. Corning, NY #1 (April 1981)	810,345	2,738	3,789	43.63	60.38
S. Corning, NY #2 (April 1981)	1,218,301	3,930	5,438	50.87	70.40
New Castle, VA (April 1981)	212,696	3,623	5,014	30.58	42.32
Miranda, CA July 1981	666,703	6,667	8,909	69.33	92.64
Gardiner, NY (Aug 1981)	596,246	5,470	7,309	30.84	41.22
Lafayette, TN (May 1982)	737,844	1,447	1,823	16.29	20.52
West Point, CA (March 1985)	695,432	4,487	5,164	38.64	48.67
Zanesville, OH (Feb. 1985)	2,798,913	3,887	4,471	46.65	53.66
Average			5,353		50.44

Table 4-6. **Comparison of Unit Costs of Components from Selected Projects**

Community (Cost Index)	Main ($/ft) 2-in	3-in	4-in	6-in	8-in	Manholes ($ each)	Cleanouts ($ each)	Mainlint Lift Stations ($ each)	Force Main ($ each)	Residential Lift Stations ($/ft)	Septic Tanks (Installed) (750-gal) ($ each)	(1,000-gal) ($ each)	Connections ($/ft)
	(Avg. Depth, ft)												
Westboro, WI (2494)	-	-	5.33 (7.6)	-	7.50 (9)	420	-	10,366	0.55	1,097	-	327[a]	-
Badger, SD (3260)	-	-	4.15 (7.9)	6.46 (10.8)	-	672	-	21,400	0.39	250	-	450	4.28
Avery, ID (3304)	-	-	8.75	-	-	2,000	100	8,554	1.64	-	-	1,500	4.61
Maplewood, WI (3376)	-	-	-	8.90 (5.7)	-	633	69	20,721	2.92	-	-	650	8.10
S. Corning, NY #1 (3452)	-	-	5.70 (7.5)	8.00 (8.0)	-	1,350	150	-	-	6,000	-	800	5.36
S. Corning, NY #2- (3452)		-	11.84 (7.6)	11.95 (6.9)	15.20 (7.8)	2,168	110	-	-	6,000	-	1,250	9.70
New Castle, VA (3452)	-	-	7.00 (5.5)	-	15.00 (9.1)	1,110	79	20,000	2.60	-	-	750	7.00
Miranda, CA (3575)	-	19.59 (9.2)	20.15 (16.7)	-	-	2,217	261	-	0.17	4,749	1,477	1,990	10.00
Gardiner, NY (3575)	-	-	8.90 (6.9)	16.29 (8.6)	17.79 (9.9)	1,056	300	15,000	0.32	2,000	600	650	4.51
Lafayette, TN (3792)	-	-	6.45 (3)	7.30 (3)	-	1,076	107	6,322	0.37	2,600	-	500	3.45
West Point, CA (4151)	7.26 (3.5)	-	-	-	-	-	300	40,000	5.60	-	-	1,600	9.73
Zanesville, OH (4153)	7.87 (3.5)	8.09	10.48	-	-	477[b]	771	-	-	1,543	-	1,335	8.71
Adjusted Average (4777 - Jan. 1991)	8.70 (3.5)	17.74 (6.3)	12.19 (7.4)	13.44 (7.2)	19.98 (9.0)	1,660	290	24,325	2.33	4,143	1,388	1,315	9.08

[a] Includes service connection.

[b] Includes ball valves and release valves.

Table 4-7. **Summary of Component Costs from Selected Projects**

Community (Cost Index)	In-Place Pipe	Manholes	Cleanouts	Lift Stations	Force Main	Bldg. Sewer	Septic Tanks	Service Conn.	Street Repair	Crossings	Site Restoration	Misc.	Total
						($/ft pipe installed)							
Westboro, WI (2494)	5.27	0.60	-	1.65	0.55	0.76	1.68	-[a]	1.47	0.22	0.75	0.06	13.03
Badger, SD (3260)	2.67	1.93	-	3.23	0.39	0.03	1.36	2.59	-[b]	0.23	-[b]	-	15.61
Avery, ID (3304)	8.57	0.60	0.25	5.11	1.64	-	12.71	0.69	-[b]	12.49	-[b]	1.33	43.39
Maplewood, WI (3376)	17.30	0.44	0.62	10.72	2.92	-	8.02	2.79	1.72	-[b]	1.29	0.03	45.85
S. Corning, NY #1 (3452)	13.36	0.44	0.48	-	-	1.62	11.59	7.72	3.57	1.12	3.08	0.65	43.63
S. Corning, NY #2 (3452)	15.11	0.72	0.32	-	-	2.51	13.80	11.87	2.37	1.64	2.11	0.42	50.87
New Castle, VA (3452)	9.89	2.40	0.78	2.88	2.60	-	9.76	-[b]	-[b]	-[b]	-[b]	2.27	30.58
Miranda, CA (3575)	24.36	1/61	1.60	-	0.17	4.94	18.24	7.44	9.48	-[b]	0.53	0.96	69.33
Gardiner, NY (3575)	15.07	1.47	0.37	0.78	0.50	0.72	3.62	2.50	2.97	2.07	0.77	-	30.84
Lafayette, TN (3792)	6.90	0.64	0.14	1.26	0.37	0.11	1.78	4.19	0.56	0.34	-[b]	-	16.29
West Point, CA (4151)	7.26	-	0.35	2.22	1.56	-	16.13	6.00	1.47	0.36	-	3.29	38.64
Zanesville, OH (4153)	8.09	0.18	1.05	-	-	9.46	6.86	8.71	5.72	-	1.12	5.45	46.65
Adjusted Average (4777 - Jan. 1991)	15.10	1.42	0.79	4.95	1.66	3.22	11.70	7.13	4.34	3.45	2.12	2.01	57.89

[a] Included in septic tank costs.
[b] Included in pipe costs.

Table 4-8. Summary of Component Costs from Selected Projects

Community (Cost Index)	In-Place Pipe	Manholes	Cleanouts	Lift Stations	Force Main	Bldg. Sewer	Septic Tanks	Service Conn.	Street Repair	Crossings	Site Restoration	Misc.
					(percent of total construction cost)							
Westboro, WI	40	5	-	13	4	6	13	-	11	2	6	1
Badger, SD	30	12	-	21	2	0	9	23	-	1	-	-
Avery, ID	20	1	1	12	4	-	29	2	-	29	-	3
Maplewood, WI	38	1	1	23	6	-	17	6	4	-	3	0
S. Corning, NY #1	31	1	1	-	-	4	27	18	8	3	7	1
S. Corning, NY #2	30	1	1	-	-	5	27	23	5	3	4	1
New Castle, VA	32	8	3	9	9	-	32	-	-	-	-	7
Miranda, CA	35	2	2	-	0	7	26	11	14	-	1	1
Gardiner, NY	49	5	1	3	2	2	12	8	10	7	2	-
Lafayette, TN	42	4	1	8	2	1	11	26	3	2	-	-
West Point, CA	19	-	1	6	4	-	42	15	4	1	-	8
Zanesville, OH	17	1	2	-	-	20	15	19	12	-	2	12
Average	26	2	1	9	3	6	20	15	12	7	4	3

cleanouts might be higher, crossings lower, etc. However, the top two categories will almost always dominate. Pipe installation costs are affected most by the depth of excavation. Where frost does not control the depth at which the sewers must be installed, shallow placement can reduce the total costs significantly. Consideration should be given to eliminating gravity drainage for basement drains. Greater use of individual STEP units can also reduce the required depth of the collectors. Several projects have shown that hybrid systems using pressure connections into gravity collectors can be cost effective in areas of undulating topography. Reducing the depth may also eliminate the need for some mainline lift stations. Shallow placement will allow the use of continuous trenching equipment as well.

The cost of installation of the interceptor tanks and service laterals includes the cost of evacuation and abandonment of the existing septic tank. Installation costs should be reduced by combining more than one connection on one tank. However, this is seldom done, except in a few instances where tanks are placed on the right-of-way, farther from the served dwellings. Many contractors are reluctant to work on private property because of the insistence of the property owner about complete restoration of their property. Several methods have been used to mitigate this problem to control the cost. Video taping of each site prior to construction helps to resolve complaints concerning appropriate restoration. Letting a separate contract for the service connections to allow a smaller contractor who is typically more accustomed to working with property owners to perform the work has been effective.

Placement of the interceptor tanks in the public right-of-way eliminates the need to enter private property altogether. This latter approach is seldom used because of space restrictions and the additional cost to the property owner for longer building sewer connections.

4.7.2 Operation and Maintenance

The most significant operation and maintenance costs of projects reviewed are labor, interceptor tank pumping and system depreciation. An operator must be on call at all times, but the time required for preventive maintenance is small. Most projects do not employ full time staff, finding that 5-10 hr/wk is sufficient for service calls or emergency maintenance.

Interceptor tank pumping is usually performed by outside contractors. Most projects are pumping each tank every 2-3 years which has been found to be more frequent than necessary. Pumping of residential tanks every 7-10 years appears to be sufficient in most instances. Commercial establishments, particularly those with food service may require pumping every 6-12 months.

Other operating and maintenance costs include administration, utilities, insurance and occasional repairs. These costs account for 20-30 percent of the total operation and maintenance costs.

4.7.3 User Charges/Assessments

User charges typically include administration, operation and maintenance, depreciation and debt retirement costs. In most projects, flat rates for residential connections are charged because water meters are not provided. Surcharges are usually placed on commercial connections based on assumed water use. In the projects reviewed, user charges ranged were $10-20/month per connection.

Flat rates are also frequently used for assessments. These may take the form of hookup charges. A two tiered system is common. The first tier is for connections made at the time of system construction. The second is for future connections. Existing users at the time of construction are usually provided the interceptor tank and service lateral while future users must pay for the tank and lateral in addition to the hookup fee.

4.8 System Management Considerations

4.8.1 User Responsibilities

Typically, the user is responsible for only the building sewer from the building to the interceptor tank. If a STEP unit is included as part of the service connection, the owner is also responsible for providing power to the control panel. Beyond these limited responsibilities, the owner must also see that access to all components of the system located on the property is unimpaired.

4.8.2 Sewer Utility Responsibilities

The utility is usually responsible for the installation, operation and maintenance of the entire system commencing at the inlet to the interceptor tank. Outside contractors may be employed to perform some tasks such as installing service connections or pumping of the interceptor tanks.

4.9 References

When an NTIS number is cited in a reference, that reference is available from:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
(703) 487-4650

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